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FATIGUE OF METAL IN WROUGHT IRON AND STEEL FORGINGS.

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(*Concluded from vol. cxlv, p. 261.*)

The product of the open-hearth furnace (*Fig. 9*) is found to give most eminent satisfaction, and has been generally adopted for making forgings.

In order that the metal of a forging should be thoroughly worked to give it strength and toughness, the ingot should be cast approximately twice its diameter. Besides this increase in diameter there is added from 10 to 25 per cent. to its length, for reasons which I will try to make apparent.

There are various defects which are inherent in steel ingots In the first place, when pouring metal into the mould, air is apt to be entrained and cause "blow-holes." In the next place, at certain stages of the cooling process gas is generated, and will cause blow-holes of itself. There are several ways of over-

coming these defects, but without doubt the most efficient is what is known as the Whitworth process of fluid compression. In this the mould is placed on a platen and is run underneath a hydraulic press. This press has a capacity of over 7,000 tons (*Fig. 10*), and under this enormous pressure the air which has been entrained in the pouring is forced out through joints in the mould, where vents have been left for that purpose, and the gases which are apt to form in the cooling of the mass are prevented from generating. *Fig. 11* shows an ingot after being taken from the mould.

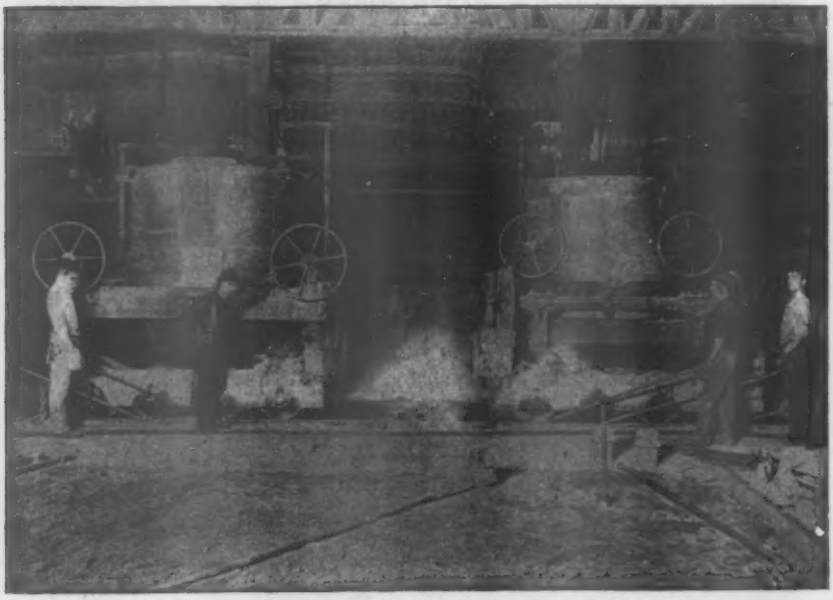


FIG. 9.—Casting an open-hearth ingot.

Another defect which is apt to occur in an ingot is known technically as "piping." The metal, when it is poured into a mould, cools and solidifies first at the surface of the mould, and as the solid metal keeps cooling towards the center, it shrinks and draws away from it. We have, if you can imagine such a thing, a pot with metal in it, which is really not sufficient to fill it properly, but which is being drawn out in all directions to fill it. This shrinkage draws principally from the

FIG. 10.—7,000-ton fluid-compression press, with ingot mould under press, Bethlehem Iron Company's Works.

center and from the top, these being the parts that solidify last. It is, therefore, to take care of this shrinkage that more metal is added to the length of the ingot than would otherwise be required. The hydraulic pressure applied at the top forces the fluid metal from this added part down through the center, and thus we are enabled to keep the latter filled where otherwise we would have a cavity or "pipe." The section of shaft on the right-hand side of *Fig. 8* shows an excellent example of "pipe."

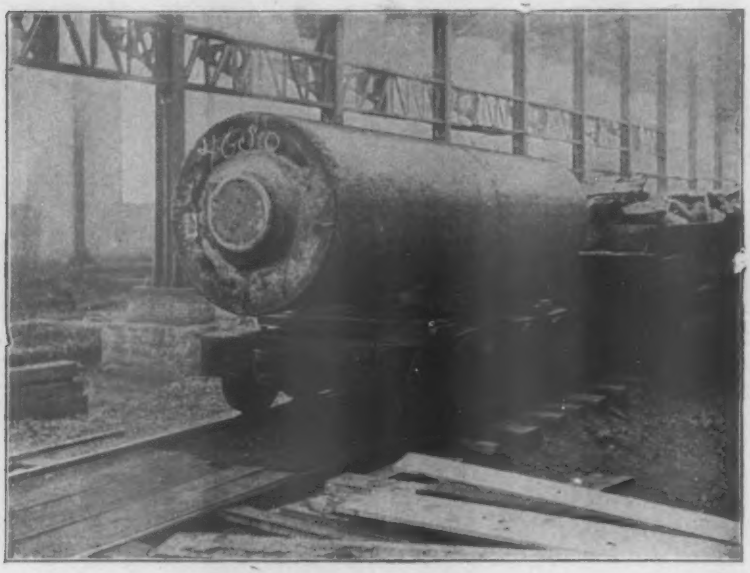


FIG. 11.—Solid fluid-compressed ingot.

Still another defect which is apt to occur in ingots, and especially in those of very large size, is what is known as "segregation." This is partly a mechanical and partly a chemical separation of the various ingredients of steel (sulphur, phosphorus, manganese, silicon, etc.), each of which has its own temperature of cooling. As the mass cools the tendency of these ingredients is towards the central and upper portions where it cools last, thus forming a central core of impurities. This does not occur to such a great extent in small ingots, but in all large ingots it does occur, and even this process of "fluid

compression" does not entirely prevent it. It does succeed, however, in giving us a perfectly solid piece of steel, with the exception of "segregation" in large ingots, and that defect I will show later can be taken care of. It is necessary that we should have an absolutely solid ingot at the beginning, because steel will not weld, and if we have any defects in the

FIG. 12.—70-ton ingot reheated and ready for forging.

ingot to start with, they cannot be remedied later by hammering, as might be the case if we were dealing with iron, which possesses to the highest degree the property of welding.

The extra length, having served its purpose of supplying metal to fill "blow-holes" and "pipes" and of collecting "segregation," is cut off and returned to scrap. The ingot is then ready for the forging process.

FIG. 13.—The Bethlehem Iron Company's 14,000-ton hydraulic forging press. This press is served by a 15,000 horse-power pumping engine.

The first operation in the process of forging is the reheating of the ingot. This operation is a very delicate one, as great care must be taken to make the heat penetrate the metal slowly and uniformly (*Fig. 12*).

As already explained, the metal in the ingot during the process of cooling is being drawn out in all directions to fill the mould. When it is cold, therefore, it is in a condition of strain throughout its interior. If we were to put a cold ingot into a hot furnace to be reheated, we would immediately expand the surface metal and pull it still further from the center, and thus put an additional strain on the inside metal. In very large ingots cracks are thus apt to be strated in the center and forgings are very liable to break in subsequent service, from the fact that they have not been properly reheated. A great many forgings fail from lack of care being taken at this time.

Next comes the forging process proper, and one of the first requisites is the proper selection of forging tools. The pressure applied in shaping a piece of steel should be sufficient in amount and of such a character as to penetrate to the center and cause flowing throughout the mass. This flowing of the metal requires a certain amount of time, and the requisite pressure should be maintained throughout a corresponding period. The hydraulic press (*Fig. 13*) fills these requirements exactly. The evil effects produced by the rapid impact of light hammers have already been shown (*Fig. 4*), and undoubtedly their use should be avoided. Under the slow motion of the press time is allowed for the molecules of the metal to move easily and the pressure is felt all through the forging. *Fig. 14* shows the appearance of the end of hydraulically-forged shafts. The center being the hottest, and therefore softest, is squeezed out, and gives the convex shape shown. The forging in *Fig. 15* show this bulging appearance very plainly. During the forging process, in which there is a gradual reduction in diameter and increase in length, a great deal of work is put into the metal (*Fig. 16*). In order that the metal should be

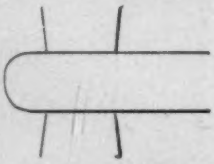


FIG. 14.—Effect of forging under a heavy press.

worked at the proper temperature, it is necessary to reheat it a number of times, and every time a blow is made by the press the metal is worked under conditions differing from those existing when the preceding blow was made, because it has cooled a little in the interval. As, therefore, when finished, no two parts of the forging have been treated the same, it is

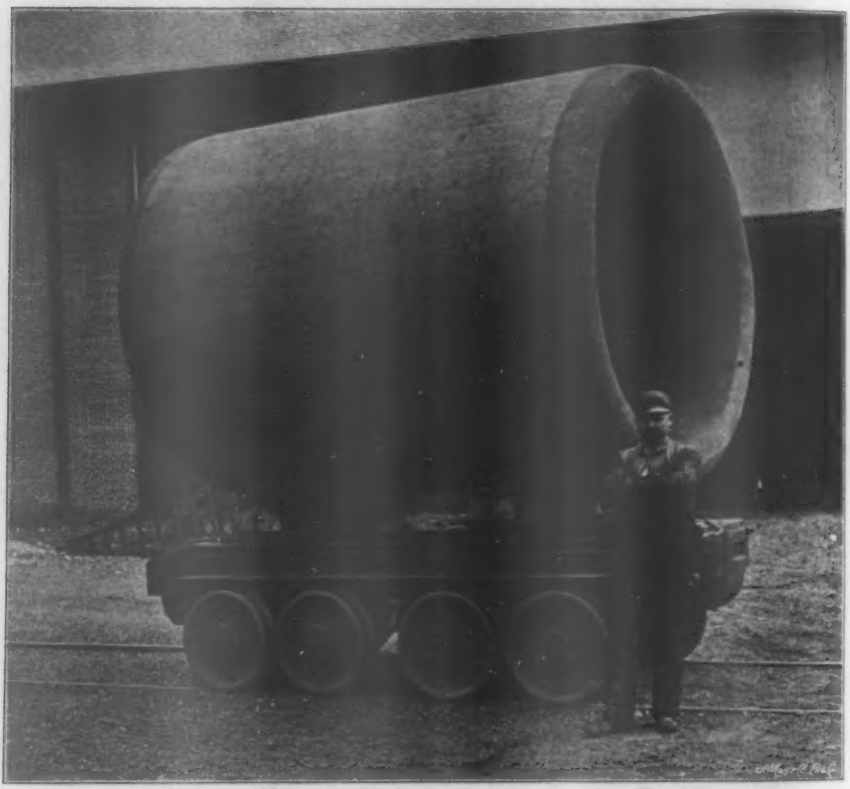


FIG. 15.—Nickel-steel conning tower for Battleship Brooklyn, showing effect of press forging. O. D., 93¾″; I. D., 76½″; length, 119″. Rough forged as shown, weight 77,600 pounds.

natural to suppose that it is full of forging strains. It is also apt to have cooling strains in it, due to the fact that it has been reheated from time to time in different places, as the forging process passes from one end of the piece to the other. To relieve these various strains, all forgings should be subjected to a final heat treatment called "annealing."

Let us consider the *rationale* of this heat treatment a little more at length.

If we note the rate of cooling of a steel ingot from the point of solidification to coldness, we will see that the temperature will fall regularly the same amount in equal divisions of time until between 1,300° and 1,200° F. a point (depending on the carbon content) is reached where the temperature suddenly stops falling and for a time either remains stationary or perhaps rises for a short time, and then the rate of cooling continues

FIG. 16.—Ingot in process of being forged into a shaft.

regularly. This point, where the change of rate takes place, is called the "recalescent" point, and from chemical and physical tests we know that a change in the structure of the steel occurs here. (*Fig. 17.*)

The fluid steel begins to crystallize at the point of solidification, and the slower the rate of cooling from there down the larger the crystals will be when the ingot is cold. At the point of recalescence, however, it would seem as if the crystallization, so to say, locks itself, for, after the ingot has become

cold, if we reheat it to a temperature below this point, on again becoming cold we will find that the crystallization is not affected, but if we reheat it a little above the recalescent point, when it is again cold the crystallization will be found to be much smaller than before.

In fact, it is known that if steel is heated slightly above the recalescent point all previous crystallization is destroyed, and a fine amorphous condition is produced at that temperature. As soon as cooling begins again crystallization sets in, and continues until the ingot is cold. As, however, the time of cooling from the recalescent point is comparatively short, the resultant crystallization is correspondingly small. It can be

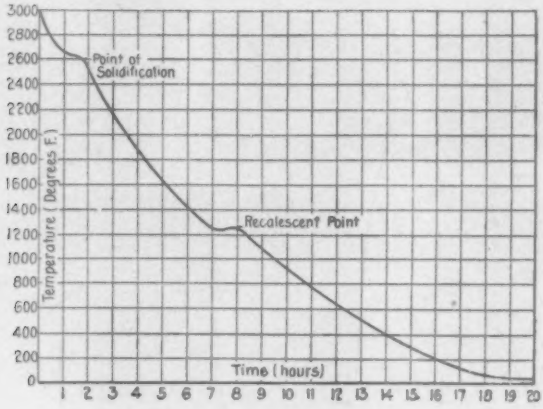


FIG. 17.—Cooling curve of steel.

readily understood that when heat treatment can completely change the internal condition of steel, it should bear an important part in the manufacture of forgings made of that metal.

Let me for a moment consider the changes which take place in the condition of the metal as it passes through the forging process. Beginning with the cold ingot (which we will assume has cooled slowly and is, therefore, composed of large crystals), we first reheat it up to a forging temperature of from 1,800° to 2,000° F., thus passing through the recalescent point, destroying all crystallization and producing an

amorphous condition. As we put it under the forging press it begins to cool, crystallization at once setting in; at the same time, however, we begin to work the metal.

The work of forging tends to check crystallization, just as disturbing water which is below freezing point will delay the formation of ice crystals. The work of forging may or may not continue (depending upon the size and shape of the finished piece) until the temperature has fallen below the recalescent point, but during this time more or less crystallization has occurred, and has been disturbed and distorted. The work of forging has, moreover, proceeded from one end of the piece to the other, the part last worked upon having crystallized considerably before work was applied to it, so that the two ends may be entirely different as far as their internal condition is concerned.

If, as is generally the case, the forging is now considered finished, it is full of pulls and strains about which we know nothing, except that they may amount to several thousand pounds to the square inch. The extent of these strains is made evident when a forging, finished as above described, has a cut taken from it in a lathe or has a keyway cut on one side. The strains in the fibers which are cut are relieved, and the piece invariably springs out of "true." To relieve these strains the forging should be carefully and slowly heated to a temperature slightly above the recalescent point and then allowed to cool slowly. By this treatment, which is called "annealing," an entirely new crystallization is established, leaving the molecules of the metal completely at rest. If the forging, on being heated slightly above the recalescent point, is suddenly dropped into a bath of cold oil, no time is allowed during the cooling process for crystals to form, and the amorphous condition of its structure at that temperature is retained. This character of heat treatment is called "oil tempering," and is followed by further heat treatment to relieve the metal of any hardening effect due to the cooling process.

An annealed forging has its elastic limit somewhat reduced as compared to its tensile strength, but its ductility is increased very considerably, as shown by its con-

traction and elongation in test pieces. The elastic limit of an annealed forging is invariably less than one-half of the tensile strength. By "elastic limit" I do not refer to the point usually determined by the drop of the beam in an

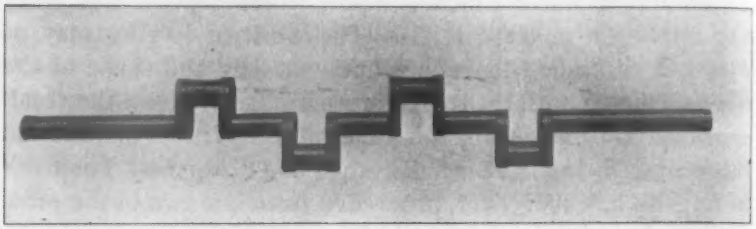


FIG. 18.—Four-throw shaft for gas engine. Shaft, 4½″ diameter; pins, 5″ diameter; length, 106⅝″; weight, 775 pounds.

ordinary testing machine, but rather to the carefully defined point obtained by more accurately determined methods, which is from 2,000 to 10,000 pounds lower. The latter figures are used in all my references in this paper, both as reported by the Government Bureau at Watertown and elsewhere. This pro-

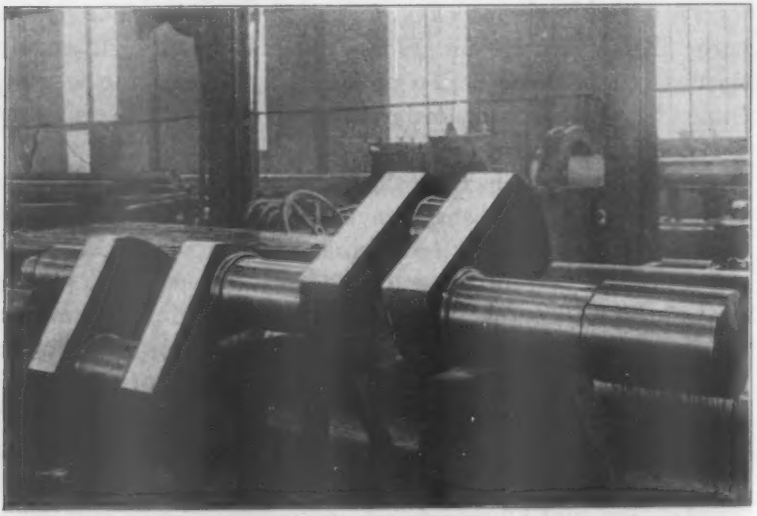


FIG. 19.—Two-throw solid crank-shaft. Diameter of shaft and pins, 12″; length, 13′ 1⅛″; weight, 9,836 pounds.

cess of annealing to relieve internal strains is a very important one. These strains are apt to develop in service, thus constituting an initial load and may throw a forging out of true, or even cause its complete failure, if they happen to act in the same direction as the external working stress.

We have already seen that bars of very high physical properties will not endure indefinitely repeated alternating stresses amounting to 40,000 pounds to the square inch. A forging strain of quite small intensity may easily act in conjunction with an external stress, closely approaching the elastic limit and bring the total working stress up to a load which, acting continuously, would soon cause failure.

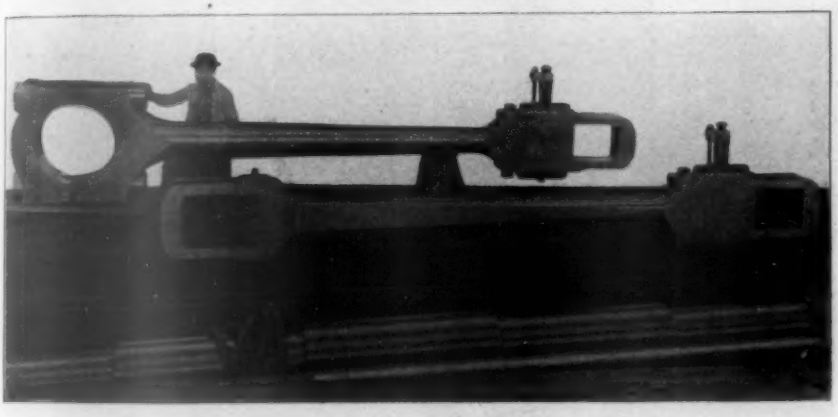


FIG. 20.—**Connecting-rods for reversing rolling-mill engine. Weight of small rod, 6,750 pounds; weight of large rod, 10,860 pounds.**

It is very evident that the twisting and other manipulation necessary in shaping the forgings, shown in *Figs. 18* and *19*, will leave strains in the metal which, unless relieved by annealing, will cause failure in service. The great mortality of this character of forgings is in part due to the fact that they have not received this heat treatment.

All steel forgings should be finished with good-sized fillets at all corners. In the forgings shown in *Fig. 20*, special care should be taken to have the four corners of the eye in the head well rounded to resist the tendency to crack at these points

should the crosshead- or crank-pin heat up and bind in the brasses.

The lowering of the physical properties by the process of annealing may be corrected by a subsequent treatment of "oil tempering."

In this treatment the forging is first reheated to a definite temperature in a vertical gas furnace, then taken out and dropped suddenly into a bath of cold liquid, which may be

FIG. 21.—Three-throw "built-up" crank-shaft. Fluid-compressed steel, hollow, oil-tempered, O. D., 11″; I. D., 4″; length, 19′ 11″; weight, 12,100 pounds.

composed of oil or any suitable fluid. The forging must be subsequently annealed, as before, to relieve it of cooling strains. The hardening effect of the sudden cooling is accompanied by a "setting" of the amorphous condition brought about by the first heating, with the result that the irregular and often coarse crystalline condition existing after forging is broken up and a uniform and finer grain ensues. By the subsequent annealing, strains are relieved and the hardening

effect of sudden cooling is removed to a desired degree; at the same time the elastic limit is increased proportionately to the tensile strength and a greater toughness is imparted to the metal, as shown by a higher elongation and contraction of area in test pieces.

In order to successfully temper a piece of steel, great care must be taken both in the process of reheating it and also in cooling it in the bath. In reheating it, the surface metal is apt to expand away from the center and thus cause cracks in the latter, as previously explained; and in dropping it into the cold bath the surface metal is apt to contract onto the center to such an extent as to cause cracks in the former. In order, therefore, to successfully temper a forging, it should be hollow.

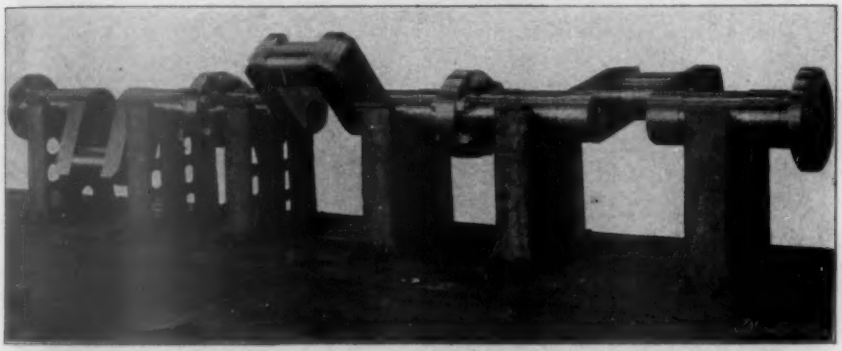


FIG. 22.—Three-throw "interchangeable" crank-shaft for U. S. Battleship Iowa. Length of each crank section, 9.6″; O. D. of pin and shaft, 16″; I. D., 7½″; weight, 8,600 pounds.

By taking out the center it can be reheated without danger of cracking, because the center metal is absent and the heat gets into the interior and expands both it and exterior together. Also, in dropping it into the cold bath there is no solid center on which the surface metal is contracted, and in that way the danger of cracking the surface during the cooling process is eliminated.

The crank-shaft shown in *Fig. 21* is known as a "built up" shaft, the shaft and pin sections being forged separately and forced into the webs or the webs are expanded by heat and shrunk on to them. The crank-shaft shown in *Fig. 22*

is on the contrary known as the "solid" type, shaft, pin, and webs, being forged out of a single block of steel. Engineers are divided in their opinions regarding the relative merits of these two types of shaft. In the built-up type the various parts are small, and can be carefully worked and, if necessary, bored and oil-tempered. The physical properties of the metal can, therefore, be raised to the highest possible limit. The forcing or shrinking process, however, always puts a strain on the metal, which will act as an initial load approaching possibly close up to the elastic limit. In the solid type, on the

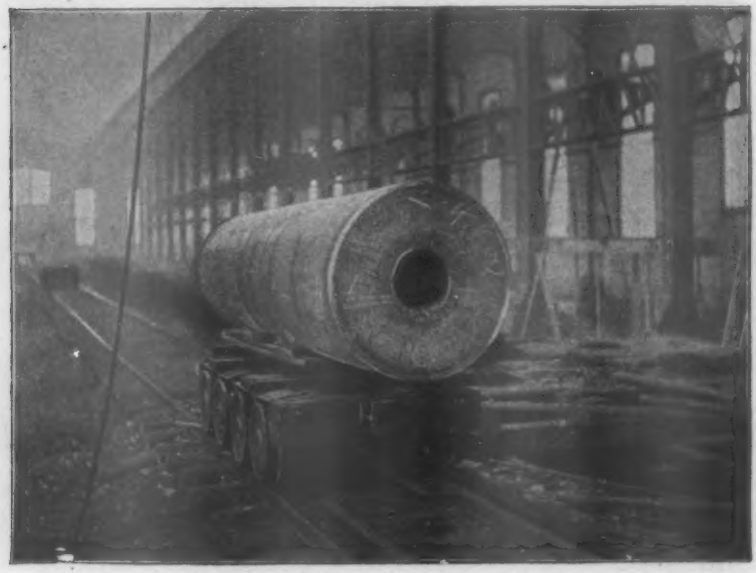


FIG. 23.—Fluid-compressed ingot, bored.

contrary, a very large ingot would be required, and as such a crooked forging can not be oil-tempered with safety, the physical properties of the metal cannot be raised by heat treatment. The metal, however, can be relieved of all strains by annealing, and if properly designed should work satisfactorily against externally applied stresses for a very long time.

As stated previously, it is necessary that a forging be hollow in order to temper it.

There are two ways of making a forging hollow. The ordi-

nary way of getting rid of the center of a forging is simply to bore it out. After boring, it is tempered, and thus the strength is restored which was taken away with the metal which was in the center.

FIG. 24.—Hollow-forging a shaft under a 5,000-ton hydraulic press at the works of the Bethlehem Iron Company.

Another way of getting rid of the center of large forgings is to *forge them hollow*. A person who has not considered the

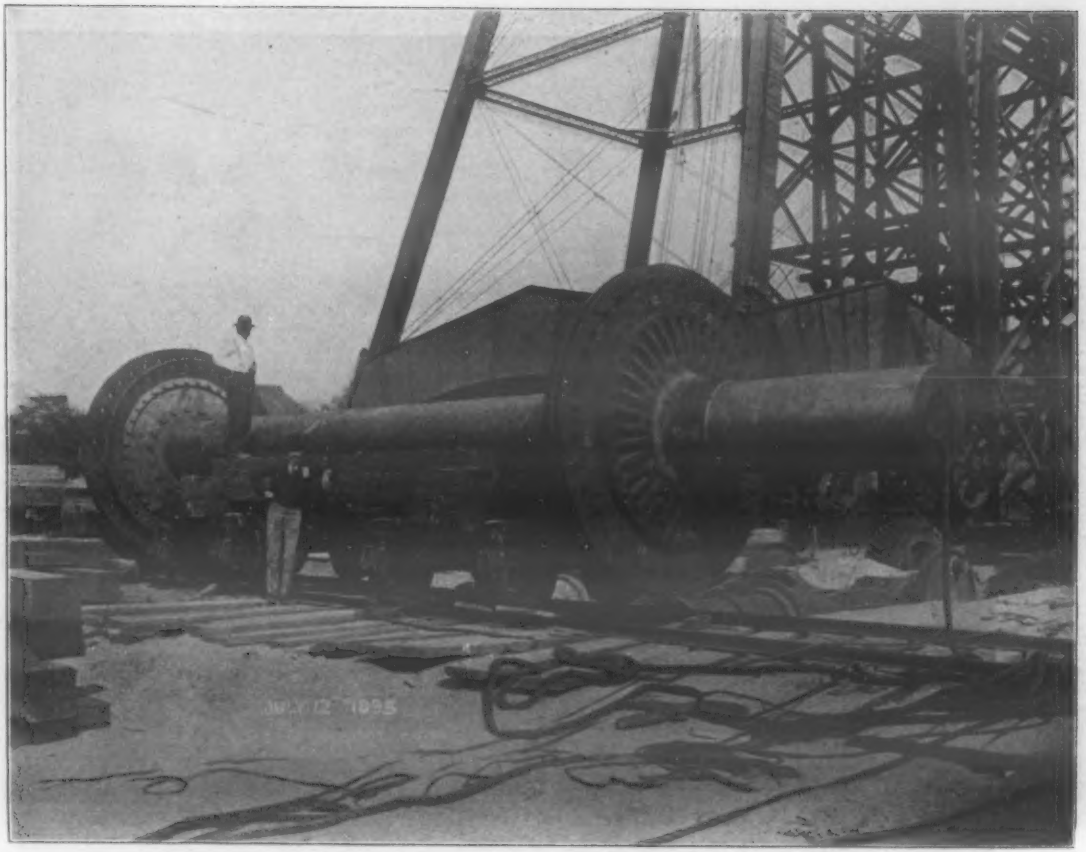


FIG. 25.—Ferris Wheel shaft. O. D., 32″; I. D., 16″; length, 45′; weight, 89,320 pounds.

FIG. 25.—Ferris Wheel shaft. O. D., 32″; I. D., 16″; length, 45′; weight, 89,320 pounds.

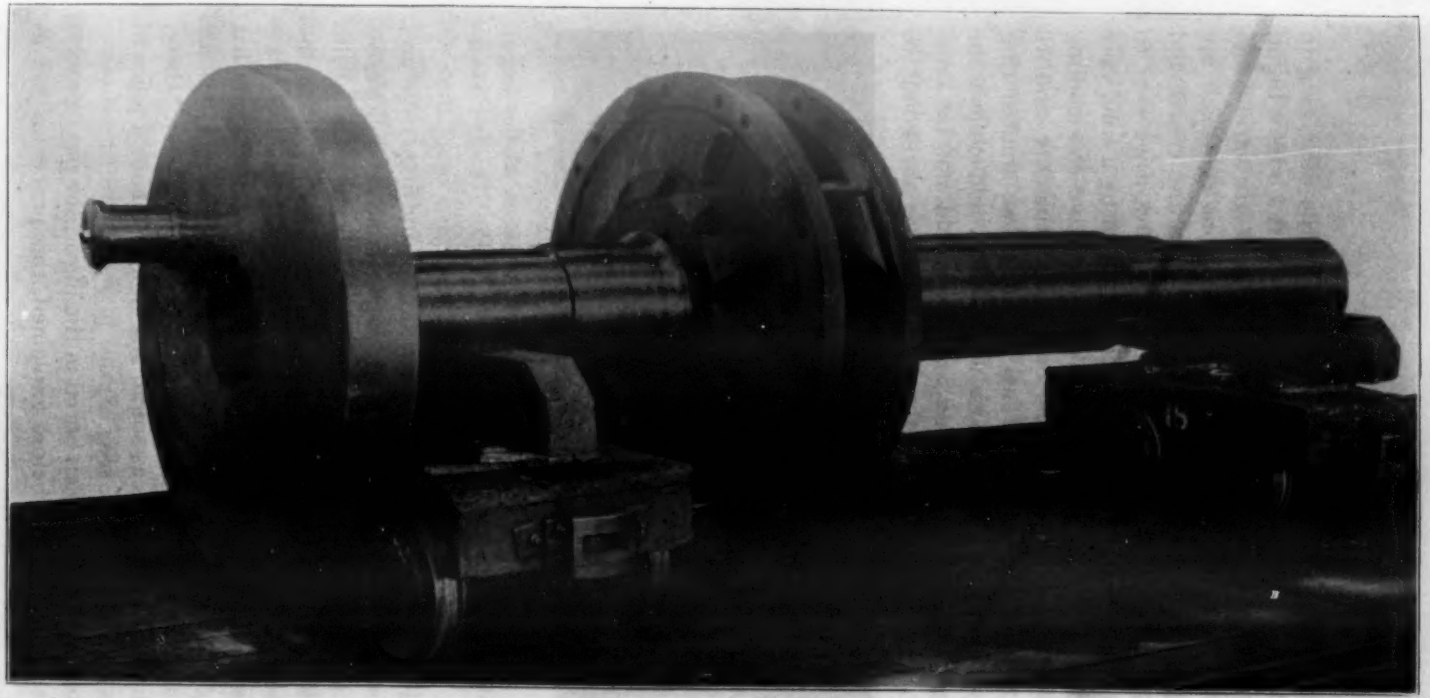


FIG. 26.—Hollow-forged shaft for Corliss Steam Engine Company, of Providence, R. I., for Union Loop Railway, Chicago. Dia. of fly-wheel hub, 28″; Dia. of bearings, 22″; Dia. of axle hole, 9″; length, 21′ 9½″; weight of shaft proper, 29,842 pounds.

subject carefully would naturally think that the first thing to do in making a hollow forging would be to cast a hollow ingot. I have already mentioned the fact that there are various defects which occur in ingots, the most serious of which are "segregation" and "piping," and that it is in the center and upper portion where those defects occur. Now, if we were to cast a hollow ingot, replacing the center metal by a solid core of fire-brick or similar material, we would have two cooling surfaces, one on the outside and one around the core, and we would transfer the position of last cooling to an annular ring midway between these surfaces, where we would collect the "piping" and the "segregation." This would not be satisfactory, because the metal there is what we are going to

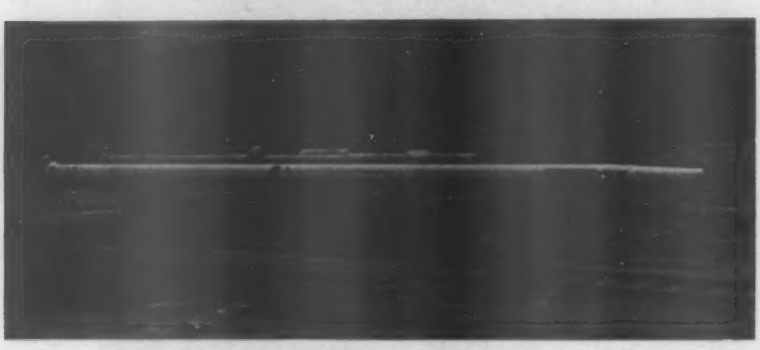


FIG. 27.—Nickel-steel propeller shaft for U. S. S. Brooklyn. Hollow-forged, oil-tempered, annealed. rough-machined. O. D., 17⅛″; I. D., 11″; length, 38′ 11⅜″; weight, 19,112 pounds.

depend upon for the strength of our hollow forging. We are, therefore, compelled to make our ingot solid as before, to collect the "piping" and "segregation" in the center and at the top, where we have added metal to the original ingot for the purpose.

Then, having cut off the top and thus gotten rid of what "piping" and "segregation" there are there, we bore out the center and so get rid of the "piping" and "segregation" there, and what we have left is as sound and homogeneous a piece of steel as can be obtained (*Fig. 23*).

After the hole has been bored in the ingot, the next process is to reheat it, and, as before explained, this process is not as

delicate a one as if the ingot were solid. The heat affects the center equally with the exterior and the two expand together and we thus do not incur the danger of cracking. When the ingot is reheated, we put a steel mandrel through its hollow center, and, subjecting the two to hydraulic pressure, we force the metal down and out over the mandrel (*Fig. 24*). We thus practically insert into the forging an internal anvil, and we have, therefore, really much less than one-half the amount of metal to work on than we would have if the piece were solid. We have, for instance, in *Fig. 25*, the Ferris Wheel shaft, 32 inches outside diameter, with a 16-inch hole, which leaves only 8 inches of metal to be worked upon between the press and the internal anvil.

A large number of hollow shafts of this type have been made for pumping engines in municipal and mining plants throughout the country, and similar shafts have also been made for engines in street and elevated railway power plants. These shafts have been about 28 inches outside diameter, 11 inches inside diameter and 25 feet long (*Fig. 26*).

The Government requires that shafts for the Navy be hollow, and this custom is being rapidly taken up in general marine practice.

Fig. 27 shows a hollow-forged nickel-steel shaft, oil-tempered, for the United States Battleship *Brooklyn*.

Test bars cut from this shaft gave a tensile strength of 94,245 pounds; elastic limit, 60,770 pounds; elongation, 25·55 per cent., and contraction, 60·58 per cent.

Professor Merriman is quoted in a paper read before the Society of Naval Architects and Marine Engineers in 1893, by R. W. Davenport, as estimating the strength of these shafts compared to solid shafts as follows, when strained to one-half of their elastic limit:

(1) Propeller shaft United States battleship *Brooklyn*, nickel-steel.

(*a*) Horse-power transmitted at fifty revolutions per minute, 15,780.

(*b*) Load in pounds at middle of a span of 12 feet on two supports, 276,200.

(2) Simple steel shaft, solid, 13 inches diameter (same weight as above).

(*a*) Horse-power transmitted under similar conditions, 5,130.

(*b*) Load in pounds under similar conditions, 89,000. Comparative strength as 3 to 1.

(3) A solid shaft of simple steel of the same strength as the hollow-forged nickel-steel shaft would be 18·9 inches diameter and weigh 53 per cent. more.

Undoubtedly the best type of hollow-forged shafts, and one which is gradually being introduced, is where the walls are of the same thickness throughout, the outside and inside diameter varying together, both being greatest at the center, where most strength is required, and smallest at the journals (*Fig. 28*). Such a shaft is designed on the principle of a girder, and offers the greatest strength for the least amount of metal. Rolls for plate mills, made after this design, are especially desirable. This type of shaft is being introduced in stern-wheel steamers on the Mississippi and Ohio rivers.

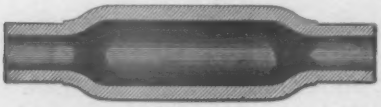


FIG. 28.—Hollow-forged shaft of girder section.

The upper sketch in *Fig. 29* shows the type of shaft which is now used on these steamers. It varies from 30 to 40 feet in length and is only from 12 to 14 inches in diameter. It is generally made of wrought iron. In the center is suspended a very large paddle-wheel, and the blow of the paddle on the water makes this center vibrate from 1½ inches to 2 inches, just such treatment as the bars in the endurance testing-machine are subjected to. This vibration eventually breaks the shaft. Somewhere on this wrought-iron shaft there has been a poor weld, or a part of it is not as strong as the rest, and it breaks there. The shaft shown underneath is of steel, has the same diameter as the other shaft, is forged solid, then bored and oil-tempered. This shaft, although it lasts longer, breaks like the other; it is not stiff enough. The type of shaft which is now being introduced in place of these is shown below. The center has been expanded over a large mandrel, so as to make

that part stiffer. It has the same weight as the first shaft, but is much stronger. Let me give you some comparative figures.

If we represent the strength of a solid wrought-iron shaft 14 inches in diameter and 30 feet in length, as shown by the upper figure, by the figure 1, a solid shaft of steel of the same dimensions would be represented by the figures 1·29; if we were to make it of nickel-steel, its strength would be represented by 2·6. Now, if we were to take the same shaft and simply bore it and anneal it, putting a 3½-inch hole through it, its strength would be represented by 1, just the same as the upper shaft. If we subsequently oil-temper it, its strength would be 1·89. A hollow-forged steel shaft of the same weight

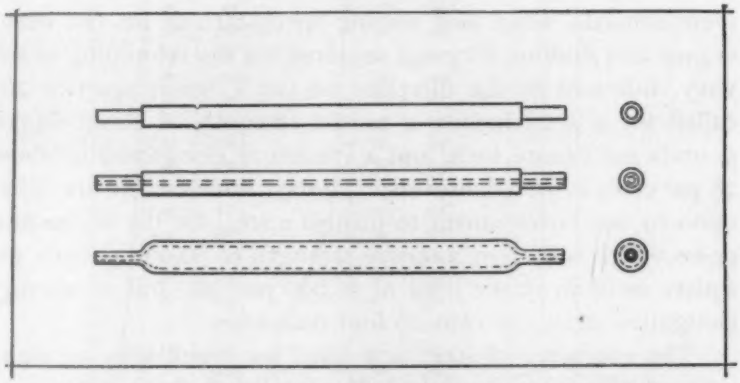


FIG. 29.—Evolution of the modern stern-wheel-steamer shaft.

as the first, but of 22 inches outside diameter, with a 17-inch hole through it, would be represented by the figure 4; if oil-tempered, 5½; if made of nickel-steel, its strength would be represented by the figure 6; and if oil-tempered, by the figure 8.

With the substitution in the trades of steel for wrought iron for engine and miscellaneous forgings, the tendency at first was to use a very mild, soft steel approaching wrought iron in the ease with which it could be handled in the shop, especially in machining.

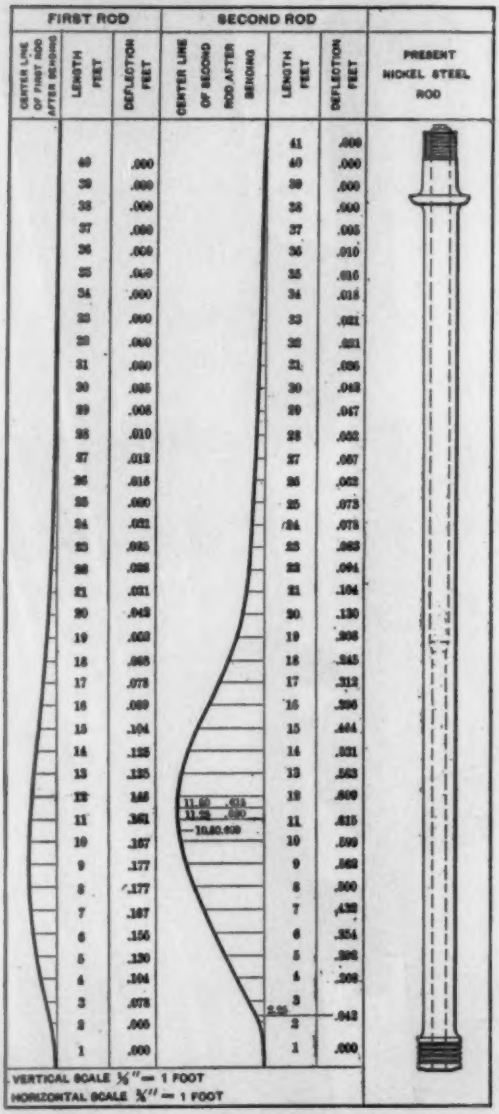
Mild steel, when of good quality, is superior to wrought iron in strength, toughness, homogeneity and freedom from

danger of imperfect welds and porous spots enclosing slag, etc. Still it does not possess the very desirable quality of high elastic strength combined with ductility or toughness in as great a degree as can be obtained without danger in a harder steel when proper precautions are taken in its manufacture.

It is only in recent years that high carbon steel has been found available for forging work. Krupp, of Essen, Germany, was the leader in substituting his soft crucible steel for wrought iron in heavy forgings. After 1870 soft open-hearth steel became a more frequent substitute, with such success that compared with wrought iron the soft steel forgings made by well-known English manufacturers soon attained a high reputation for their quality. It was, therefore, natural that our Government officials, when first issuing specifications for the heavy engine and shafting forgings required for the rebuilding of our navy, followed in the direction of the English practice and called for a steel having a tensile strength of about 65,000 pounds per square inch, and a minimum elongation of about 28 per cent. in four diameters. To-day, however, we are called upon by our Government to furnish a steel for the above purposes which will show a tensile strength of 80,000 pounds per square inch, an elastic limit of 50,000 pounds, and an average elongation of 25 per cent. in four diameters.

The character of steel now used for crank-pins by many railroads furnishes a marked illustration of the practicability of using high carbon steels. When steel was first used in such pins in place of wrought iron, a soft low-carbon steel was generally employed, and the failures due to "fatigue of metal" were almost as numerous as when wrought iron was used. The broken pins showed what has been called "a fracture in detail," a gradual parting of the steel extending inward all around the piece, undoubtedly produced by the working strains repeatedly approaching the low elastic limit of the soft steel. On substituting a steel with an elastic limit of 45,000 to 50,000 pounds per square inch, failures were greatly diminished, without changing the diameter or shape of the pins.

These same facts are true to the present day regarding steam-hammer rods.



* FIG. 30.—Comparative failures of high- and low-carbon steel piston-rods of 125-ton hammer, Bethlehem Iron Company.

* By H. K. Landis in *Iron Age*.

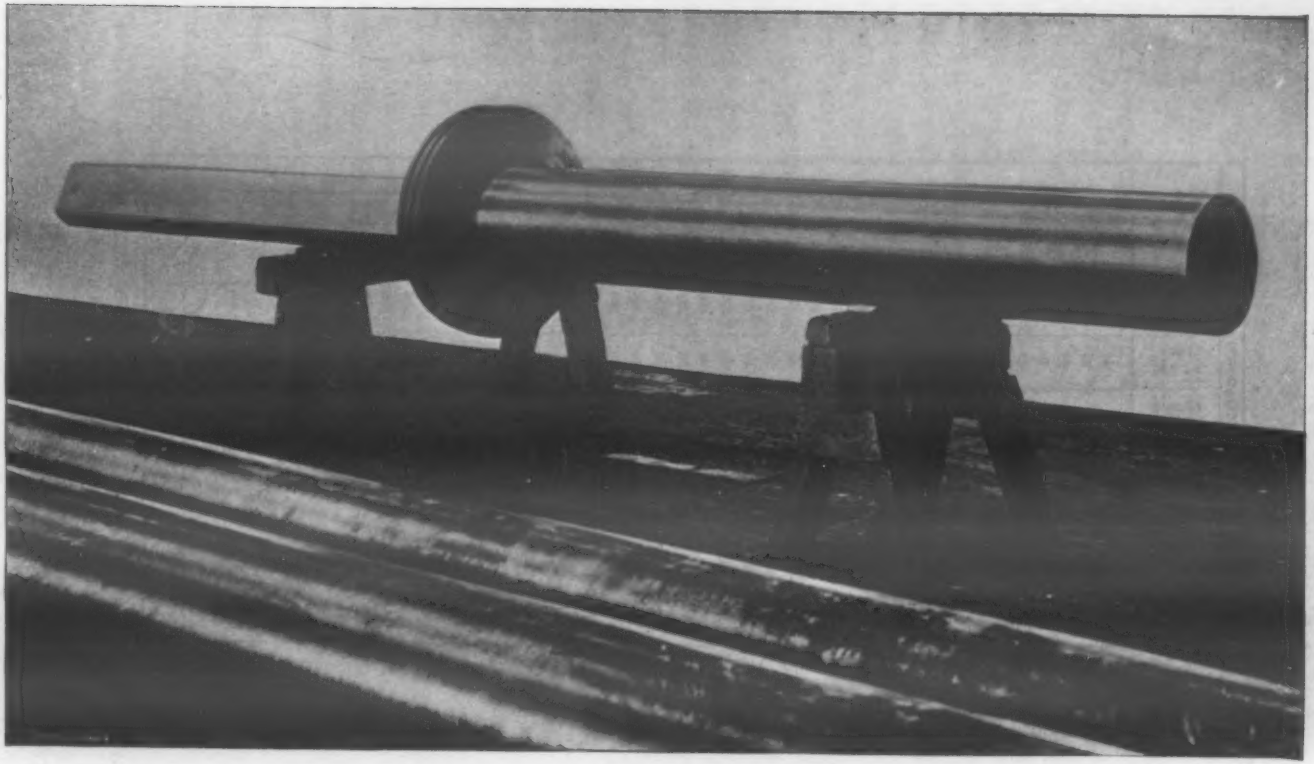


FIG. 31.—Nickel-steel, oil-tempered, hollow steam-hammer piston-rod, with piston forged on. Dia. at lower end, 16″; total length, 18′2¼″; weight, 9,522 pounds.

Fig. 30 shows the experience of the Bethlehem Iron Company with rods for their 125-ton hammer.

The first rod was made from high carbon open-hearth steel, hydraulically forged with a 4-inch hole running through the entire length and having an outside diameter of 16 inches. The failure of this rod was attributed to partial crystallization and to its being of too high carbon steel, and, therefore, too brittle. These were the usual reasons given for failures under similar conditions in those days.

Consequently, the next rod was made with a much lower carbon, in the hope that it would withstand the effects of shock better. This supposition proved to be erroneous, and it failed after a shorter service than the first, and its failure was much more serious.

About this time the advantages of material with high elastic limit became known, and the third rod was made of nickel-steel. The dimensions were somewhat changed, however. The outside diameter was from 16 to 17 inches and the hole was made 8 inches in diameter for 22 feet from the top, the balance was made 7 inches instead of 4 inches, as before. This rod has fulfilled all expectations. The amount of deflection of the two rods which failed is shown in the figure.

Fig. 31 shows the character of rod now made for users of rods who want something that will last a long time.

In general, it can be stated that experience shows that where high duty is demanded of a forging, mild steel of a tensile strength of 60,000 pounds is not the best material to use, owing to its low elastic limit. The tendency is now towards the adoption of a higher carbon steel, followed by such treatment as will raise the elastic limit relative to the ultimate strength.

Engine builders, although fully alive to the advantages of the use of high carbon steel, are deterred from its use by the fact that it is very tough, and, therefore, the cost of machining in the shops is high. In competition with each other, the engine builder who uses the lower carbon steel can bid lower than the one who uses the better grade. It is, therefore, to the interest of the engineer, who specifies what he wants, to insist

FIG. 31.—Nickel-steel, oil-tempered, hollow steam-hammer piston-rod, with piston forged on. Dia. at lower end, 16″; total length, 18′2½″; weight, 9,522 pounds.

upon his specifications being worded properly, so that all the bidders can base their calculations on the same grade of material.

The engineer does not want his engines composed of a weak and unreliable material merely because the engine builder finds it easier and cheaper for him to manipulate it in shaping. He should follow the progress in steel-making and insist upon getting the best he can afford to buy. The first cost may be a little greater, but he will save by getting a material much stronger and stiffer and which will receive a higher polish. The lessening of friction of such parts will alone pay the difference in cost by the saving in fuel and lubrication.

Experience must teach the engineer what quality of steel is best suited for the various parts of his engines, and his judgment must determine whether he will use a high quality and decrease the size of his forgings or a cheaper grade and put in more metal and take greater risk.

Although forgings can be made to fill a large variety of specifications, they can, in general, be divided into six classes, as follows:

(1) Mild steel, annealed.
(2) Medium hard steel, annealed.
(3) Medium hard steel, oil-tempered.
(4) Nickel-steel, annealed.
(5) Nickel-steel, oil-tempered, No. 1.
(6) Nickel-steel, oil-tempered, No. 2.

Each of these classes is supposed to cover a series of grades of steel, varying in strength several thousand pounds. In selecting the material for the forgings of an engine and in drawing up the specifications therefor, the premise should not be omitted that "all forgings shall be made of open-hearth steel," and that "they shall be carefully annealed after forging."

Large shafts and similar forgings, crank and crosshead pins should be made of fluid-compressed steel, and should be hydraulic forged, not hammered. Wherever practicable, an axial hole should be bored through shafts to insure absence of any internal defects. If forgings are oil-tempered, the hole can be made larger in diameter than if they are simply an-

nealed, and where the hole is 7 inches in diameter and above, they can be hollow forged on a mandrel. A hollow-forged, oil-tempered forging insures the highest attainable qualities, and can be especially recommended where the maximum strength with the greatest lightness is desired.

Where it is important that the quality specified should be obtained in the more important parts, physical tests of the forgings as delivered should be demanded. For such tests prolongations should be left on the end of forgings for the purpose of having test specimens cut from them after the forging and treatment have been completed. Such prolongations should receive no greater reduction than the forging at its largest part.

The following table shows the average physical qualities that should be obtained in forgings made of the several grades of steel mentioned, the test specimens being 2 inches long between measuring points and ½ inch in diameter and cut from full-sized prolongations of the forgings after treatment; the elastic limit being determined not by the drop of the beam, but by an electric micrometer:

	Tensile strength.	Elastic limit.	Extension percentage.	Contraction percentage.
Simple Steel.				
(1) Annealed	58,000	28,000	28	55
(2) "	80,000	37,000	23	45
(3) Oil-tempered, with axial hole	80,000	45,000	25	50
Nickel Steel.				
(4) Annealed	80,000	45,000	23	45
(5) Oil-tempered, with axial hole	80,000	50,000	25	50
(6) " " "	90,000	60,000	22	50

I trust that I have been able to make plain in this paper that the causes of failure in forgings are in general to be found either in their design, quality of material or character of treatment in manufacture. Almost all forgings are subjected to alternating stresses. If they are composed of a quality of material which has a high elastic limit, properly proportioned, so that the stresses applied fall well below this limit, and if then they are free from flaws, defects and initial stresses, they should resist fatigue indefinitely.

DISCUSSION.

MR. G. WHITEFIELD CHANCE:—In Howe's Metallurgy of Steel (p. 198) is cited a case where 18,140 bendings reduced tensile strength from 70,000 to 48,000, and elongation from 20 per cent. to 2·6 per cent.

MR. PORTER:—Mr. Howe, contrary to his usual accuracy of detail, omits to mention what the fiber stress on this bar was. I rather infer that the bar was bent in a vise, or similarly, and that the fiber stress considerably exceeded the elastic limit of the metal; the result quoted would then have been obtained.

MR. CHANCE:—Mr. Howe also says: "Comparing cases in which the stress on each variety is a given percentage of their estimated tensile strength under single load, hard steel breaks down much the earliest." This is a comment on some tests made of the same kind as those you spoke of.

MR. PORTER:—Certainly—this is what my tables show. For instance, in Table No. 2, 34 per cent. carbon steel, with a tensile strength of, say, 90,000 pounds per square inch, and an elastic limit of 42,300 pounds per square inch, stands 14,100,000 revolutions under a fiber stress of 35,000 pounds per square inch or 40 per cent. of the ultimate strength.

Fifty-five per cent. carbon steel, however, with a tensile strength of, say, 100,000 pounds per square inch, and an elastic limit of 47,000 pounds per square inch, stands only about 400,000 revolutions under a fiber stress of 40,000 pounds per square inch or the same percentage of tensile strength.

What I have endeavored to show is that under the *same* fiber stress the higher carbon steel will outlast the lower.

MR. CHANCE:—You mentioned the fact that in the endurance tests the load was within the elastic limit in the extreme fiber, but would the load suddenly applied with high rotative speed be within the limit? We are aware that the suddenly-applied load is very disastrous.

MR. PORTER:—I am not aware that any difference has been observed in the result of fast and slow rotation. In fact, I have been informed that Mr. Howard, at Watertown, has seriously considered putting in a steam turbine, running about

20,000 revolutions a minute, so as to be able to make his tests more rapidly.

MR. PAUL A. WINAND:—There is one point in Mr. Porter's paper which did not seem clear to me. He stated, if I understood him correctly, that specimens, taken from pieces finally broken by fatigue, showed the same tensile strength as the material before being subjected to fatigue.

Now, if this refers to specimens taken from shafts fatigued by rotation under strain, the result may depend entirely on the location in the cross-section from which the specimens were taken. The strain is obviously maximum at the periphery of the cross-section and gradually vanishes at the center. The material near the center has, therefore, not been subjected to appreciable strains, and a test piece taken from that region would practically be in the original condition of the material. Even at some distance from the center, the strains may have been quite below the elastic limit, and the material might stand an unlimited number of reversals of such strains. If, however, the piece has been fatigued by reversals of purely tensile, not bending, strains, it would be immaterial from what portion of the cross-section the test pieces were taken.

MR. PORTER:—The tensile test specimens are annular in shape, the center having been bored out. The outside is 1 inch in diameter, the inside diameter is .9 inch. All the metal to be tested, therefore, has been thoroughly fatigued.

MR. JAMES CHRISTIE:—It might seem unnecessary at this day to demonstrate again the great superiority of steel over wrought iron, for the purpose described by Mr. Porter, except for the occasional complaint of some ultra-conservative, whose thoughts wander back to the good old days, whose faults are apt to be forgotten.

The high speed and great carrying capacity of the modern steamship and railway train, are largely due to the use of good steel in construction, and it is doubtful, if equal results could be had as economically with the old form of wrought iron. We have also passed the era of extreme soft steel, and the tendency is to use harder grades, with the same advantages everywhere, as described by Mr. Porter.

The experiments on fatigue of strength, described by Mr. Porter, are interesting, and give us further information on a subject on which there is yet much to learn.

It is still doubtful if destruction can occur from indefinitely prolonged fatigue, when the stresses are known to be well below the elastic limit. This has been suspected heretofore, but the exact intensity of stress was not always clearly defined. An interesting problem belonging to the physics of steel, is the effect on the material of elastic fatigue. This has been observed in connection with material exposed to prolonged vibration, and is indicated by a loss of elastic energy, after a period of vibration, and restoration by rest.

It may be demonstrated by future experiments, that there exists some intimate connection between elastic fatigue and the fatigue of strength.

MR. PORTER:—If the distinction which Mr. Christie makes between "elastic fatigue" and "fatigue of strength" is respectively fatigue of metal tested *below* and *above* the elastic limit, I can only refer him to Table No. 1 and to the records of endurance tests at Watertown, which are all made under a fiber stress well below the elastic limit.

As far back as 1886 Mr. Benjamin Baker, in his paper presented to the American Society of Mechanical Engineers, in commenting on endurance tests made on material for the Forth Bridge, says: "An illusion entertained by some engineers, that alternating stresses are destructive only if the stress exceeds the elastic limit, is effectually disposed of by these experiments, because none of the stresses in question exceeded the said limit, and some of them were very far below it."

MR. A. E. OUTERBRIDGE, JR.:—Have investigations been made to determine whether the expansion of the iron ingot mould, caused by the heat of the molten steel, affects the density of the ingot? In other words, do you think it is possible that "piping" may be due, in part, to the receding of the mould from the ingot while the latter is still in a semi-fluid or a plastic condition?

MR. PORTER:—The "sink-head" or added length of ingot supplies metal by ferrostatic head as the mould expands. The

fluid compression prevents piping by adding to the ferrostatic head, and forcing the metal of the sink-head down into the "pipe."

MR. OUTERBRIDGE:—The question was suggested to my mind by my experience with cast iron, more particularly in the special work of casting car wheels. Formerly, a simple "chill ring" was used to suddenly cool the casting and to form the hard-chilled tread of the wheel; this ring expanded when heated by the molten iron, so that, in a few moments, after a wheel had been poured, it was possible to insert a knife-blade between the chill ring and the casting; moreover, the space was usually greater upon one side than upon the other, owing to some accidental cause, such as a draft of air striking one side of the chill ring, and the effect upon the wheel was apparent when it was broken in order to examine the fracture, the chilling effect being deeper on one side than on the other. To overcome these defects, a very ingenious invention was made some years ago, now known as the "contracting chill;" this is a double ring, or rather two concentric rings connected by webs or radial arms, the inner ring being divided, by sawing, or otherwise, into a hundred or more separate segments, each segment being attached to the outer ring by a single arm. When the sectors of the inner ring become heated by contact with the molten metal, they all simultaneously *move inwards toward a common center*, because the radial arms grow longer when heated, and the cold outer ring prevents any movement outwards. This contracting chill, therefore, follows up the casting as it cools and hugs it closely, thus producing a uniform chilling effect upon the periphery of the wheel and preventing annealing of the chilled metal, or return of the combined carbon to the graphitic form. The purpose of my inquiry was to ascertain whether this ingenious principle has been applied to ingot moulds, and if no such experiments have been made, would it seem to you *a priori* likely that a contracting, instead of expanding, iron ingot mould might tend to produce a denser ingot, and thus to prevent or diminish piping?

MR. PORTER:—I am unable to say whether any work has

been done in this direction or not. I imagine not, however, as the large masses of steel usually cast require moulds built very rigidly to resist the enormous internal pressure.

MR. OUTERBRIDGE:—You have spoken of the advantage of hollow forgings and of boring through the center of steel shafts. Can you tell me whether there is any evidence of a release of cooling strains in the shaft traceable to the act of boring the hole?

MR. PORTER:—Yes, most decidedly, a solid shaft may be perfectly straight, but after boring it will invariably be bent. This is true also of turned shafts.

Key-ways, cut in straight shafts, will release strains which will allow the shafts to spring a considerable amount in their length.

Annealing will relieve these strains.

MR. OUTERBRIDGE:—In explanation of this question, I would again refer to cast iron. We all know that a very minute flaw in a cast-iron test bar (such as a tiny blow-hole, or a small piece of slag, sand or dirt) will cause great weakening of the bar, far more than is attributable to the area of the hole or defect. I have found, however, that a hole of quite considerable size may be drilled across the section of a test bar at the point of intended rupture upon the testing machine, and the bar, instead of being weakened, is somewhat strengthened thereby. If a hole $\frac{3}{16}$ inch diameter be drilled through a bar of 1 inch section, the fracture will often occur through solid metal at one side of the hole. In a number of such tests, I found that the majority of bars with holes drilled across the section were stronger than companion bars, cast in the same mould, not drilled. I have attributed this gain in strength to partial release of internal strains, caused by irregular cooling of the mass, and have heretofore expressed the belief that rearrangement of the molecules takes place in the bar, in a manner somewhat analogous to that which occurs from annealing by heat or from mechanical vibration.

In a car-wheel casting, these cooling strains are enormously increased by the very sudden chilling of the rim, so that a car wheel will explode, or break in two or more pieces with a loud

report, if allowed to cool in the air. After being annealed, a car wheel is the very strongest kind of casting; yet the composition of the metal itself is in no way altered, but the cooling strains have been eliminated.

I have supposed that these cooling strains were peculiar to, or at least excessive in, cast iron, and would not occur to such an extent in steel; therefore, I was desirous to know whether your experience has shown that the act of boring a hole through a steel ingot, or a steel shaft forged from an ingot, has any appreciable effect in increasing its strength by relieving cooling strains.

In conclusion, Mr. President, I wish to add that the paper of Mr. Porter is one of rare interest and importance, and to express my individual appreciation of its value. Although another engagement presses upon me this evening, I have felt unwilling to lose a word of it, and I think, Mr. President, that a special vote of thanks to Mr. Porter should be recorded upon our minutes, and I, therefore, make a motion to that effect.

(Mr. Outerbridge's motion was numerously seconded, and unanimously adopted. The President thereupon formally presented the thanks of the Section to the lecturer.)

Stated Meeting, Tuesday, January 12, 1898.

SOME ILLUSTRATIONS OF THE INFLUENCE OF GEOLOGICAL STRUCTURE ON TOPOGRAPHY.

By Benjamin Smith Lyman.

Capt. D. G. Robinson's excellent map of the Punjab Salt Range and of the country northward finely illustrates in many places the influence of the geological structure upon the face of the country. The map was made about forty-five years ago, more particularly for military purposes, and is on the scale of a mile to the inch, with shaded topography. Certain portions of the map are especially interesting from the distinctness of the geological indications.

Near the eastern edge of the map, and about twenty miles northwest of the town of Jhilam, several ridges (*Plate 1*) bend round so as to form the northeastern end of as many concentric ellipses, with the long axis in a northeast and southwest direction. The ridges evidently consist of harder beds of rock separated by softer beds that underlie the hollows between. In the main body of the ellipse the harder rock beds seem to have so steep a dip as to make the beds perhaps nearly vertical and, therefore, nearly parallel on one side to those on the other. But where the principal ridges curve round at the northeastern end of the ellipse, a much gentler dip outwards is shown by the great steepness of the inner slopes and the comparative gentleness of the outer ones. Many of the subordinate outermost ridges have their crests worn down towards the small streams that cut across them, and thereby form sharp little peaks half way between each pair of those streams. The space in the interior of the ellipse of the principal ridges appears to be mainly filled with some level-bedded, probably old-alluvial soft formation. Yet here, too, the small streams have cut down into the steep dipping underlying rocks, and have formed numerous narrow, short valleys parallel to the main ridges, and showing the persistence of the same structure of the older beds throughout the ellipse. It is plain that the ellipse is caused by a saddle in the rocks, and that, if the rock beds of the principal ridges were restored, so as to be continuous over the central part of the ellipse, a form would result, closely resembling an overturned ship or boat, of which the prow would be towards the northeast.

Another place (*Plate 2*) within half a dozen miles east of the Indus, not far from the northwest corner of the map, and about twenty miles southwest of Attock, shows concentric ridges in a somewhat similar oval shape, forming roughly a complete ellipse half a dozen miles long, northwest and southeast, by a mile and a half wide. In this case, however, it is clear, upon careful inspection, that the rock beds do not lie in the shape of a saddle but in that of a basin. For towards the southeast end of the ellipse, and in a less degree along the northeast side, the steep escarpments on the outer side and

TOPOGRAPHY INDICATING GEOLOGICAL STRUCTURE.
PART OF A MAP OF THE PUNJAB SALT RANGE AND NORTHWARD,
BY LT. D. G. ROBINSON, BENGAL ENG'RS,
1851–57.
ORIGINAL SCALE:– 1 MILE TO AN INCH.
0
1
2
3
4 MILES
5
Kalika
Kalabagh
Jatta mora of Bantha
Chakmiana
Jatta ka mora
Bantha
Ammila
Mera
Boodhan
Bokra
Kaydhur
Salt
Pde
Chakesar

PLATE I.

TOPOGRAPHY INDICATING GEOLOGICAL STRUCTURE.

PART OF A MAP OF THE PUNJAB SALT RANGE AND NORTHWARD,
BY LT. D. G. ROBINSON, BENGAL ENG'RS,
1851–57.

ORIGINAL SCALE:– 1 MILE TO AN INCH.

0 1 2 3 4 MILES 5

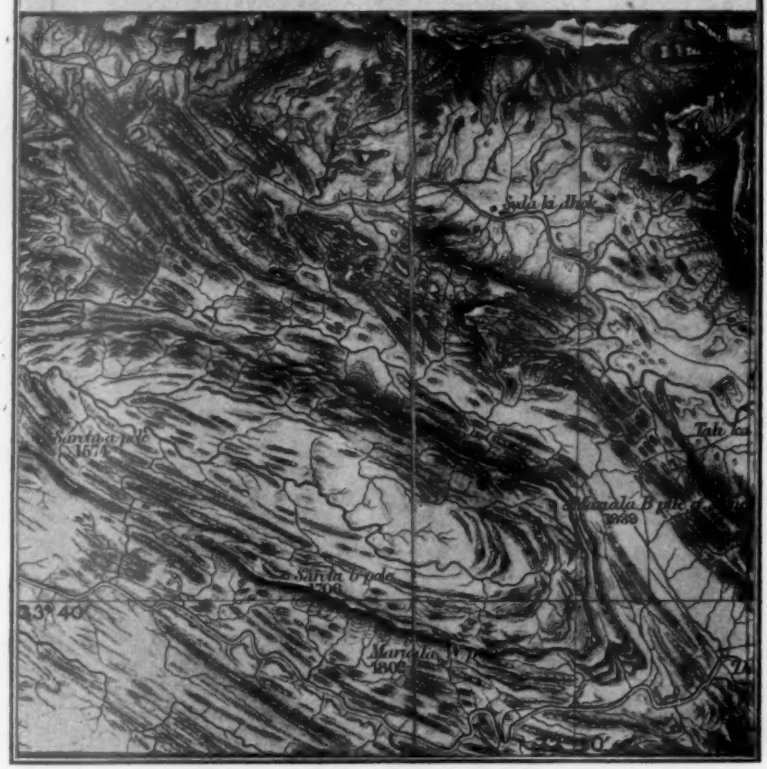


PLATE II.

the comparatively gentle slopes on the inner one show that the dips are towards the center of the ellipse. Along the southwestern side the same thing can likewise be discerned, but the dips seem to be steeper, more nearly approaching the vertical, and continue so for a couple of miles to the southwest, where the lower rock beds become gradually covered up by the overlying alluvium-like horizontal softer beds already noticed. A couple of miles northeast of the ellipse similar indications show that the rock beds form another nearly parallel basin, but the ridges are more broken up, and the geological structure is less easily made out. This basin is distinctly and narrowly closed by ridges on the northwest, but opens out towards the southeast, and the ridges become less continuous and less clear. Between the two basins the rock beds are in the form of a saddle, but very closely pressed together and broken up, so as to leave the geological structure less obvious. It appears, nevertheless, that the saddle broadens out towards the northwest.

Still another place (*Plate 3*) about twenty miles further south, has numerous nearly parallel northwest and southeast ridges, with a couple of the stronger ones bending round at the northwest to form the end of an ellipse. Here again the steep outer escarpments and gentler slopes towards the center show that the rock beds are in basin shape. Along each side of the ellipse they appear to be more nearly vertical, with the two sides rather closely pressed together. Northward from the end of the ellipse the rock beds form a saddle of somewhat irregular shape, and to the northeast another basin, the whole so compressed as to be broken up into rather disjointed parts. The alluvium-like upper soft horizontal beds also reappear here to mask the underlying harder layers.

Yet one more place (*Plate 4*) in the Salt Range itself, near its eastern end, shows a still more varied geological structure within the space of a few miles. At the point marked "Choombi pole" there is a curved nearby rectangular ridge, with steep outer slopes and gentler ones inside, indicating a small basin, broken through along the eastern side by the Bonhar River. The ridges on the east show by their slopes steep,

perhaps vertical, dips; on the west, gentler ones towards the middle of the basin, and on the northwest still gentler, with the crests formed into little peaks between the small transverse streams. To the northeast of the central basin the ridges are roughly concentric, but further on become rather sharply angular in their course, as if crushed together and broken. To the north the main river valley is very much filled up with the same alluvium-like, soft, horizontal beds already noticed, mostly covering up the harder underlying rocks, but leaving some of them visible in short ridges that betray not only steep dipping beds but a continuance of the partly crushed and broken condition of the rock beds of the neighboring hills. Yet some of the principal curves of the more disturbed rock beds are parallel to one another even at a distance of several miles. This illustration has also been used in the discussion of the paper read by Prof. J. C. Branner before the American Society of Civil Engineers last November.

It is evident that the carving out of the strongly-marked ridges and hollows in accordance with the geological structure has been effected by water—the rains and streams—leaving the harder rock beds to stand forth and the softer ones to be eaten away where not protected by overlying hard ones. In that torrid climate the water has acted mainly in its liquid form, with the help of weathering in a moist atmosphere during part of the year, but without the aid of frost to disintegrate the rocks. In some places lime rock may have been to some degree dissolved away by the waters, but their action appears to have been mainly mechanical.

The clear indication of basins and saddles within the small space of a few miles is owing partly to the fact that the succession of rock beds, originally laid down as sand, silt or the like, one on another at the bottom of the sea, and afterwards more or less consolidated, is made up of a great number of not very thick beds or masses of harder rock separated by softer beds that are likewise not in very heavy, thick masses; and partly to the fact that the whole series has been so strongly compressed and is of so yielding a character as to have been crumpled into very numerous, comparatively small waves with

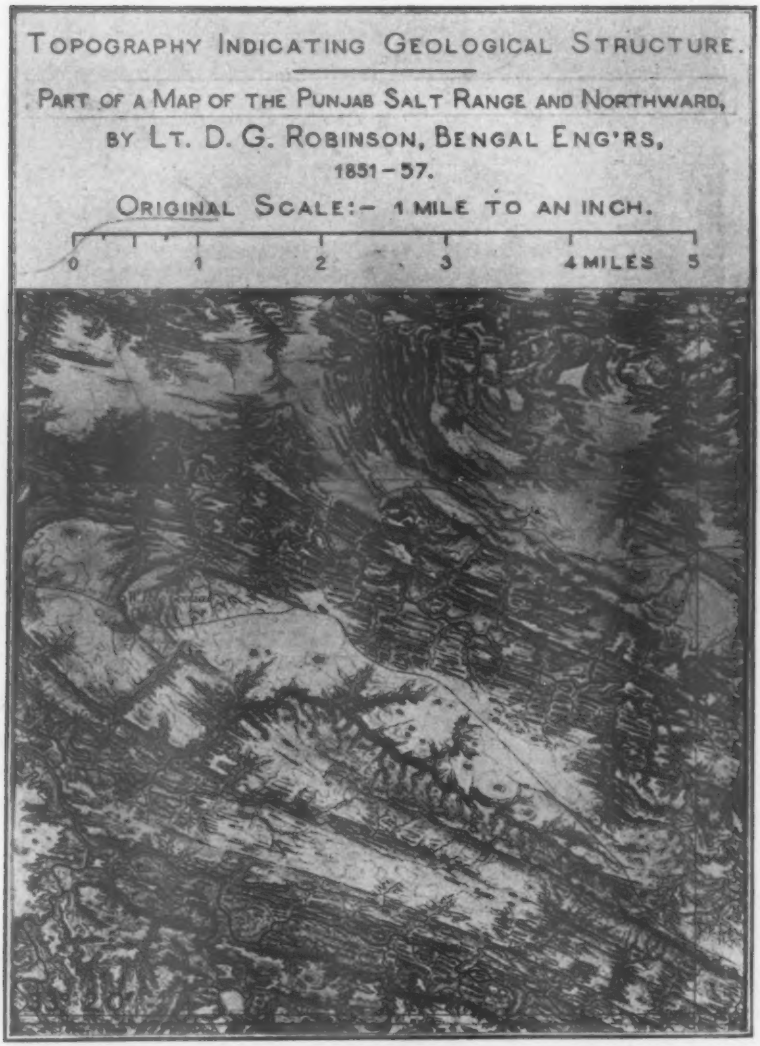

TOPOGRAPHY INDICATING GEOLOGICAL STRUCTURE.
PART OF A MAP OF THE PUNJAB SALT RANGE AND NORTHWARD,
BY LT. D. G. ROBINSON, BENGAL ENG'RS,
1851-57.
ORIGINAL SCALE:- 1 MILE TO AN INCH.
0
1
2
3
4 MILES
5

PLATE III.

TOPOGRAPHY INDICATING GEOLOGICAL STRUCTURE.

PART OF A MAP OF THE PUNJAB SALT RANGE AND NORTHWARD,
BY LT. D. G. ROBINSON, BENGAL ENG'RS,
1851–57.

ORIGINAL SCALE:– 1 MILE TO AN INCH.

0 1 2 3 4 MILES 5

PLATE IV.

little basins and saddles. These folds are, to be sure, irregularly combined and in many places fractured and crushed into discontinuity. The overlying, more recent, still soft, level-bedded, alluvium-like material of the plains partially masks and obscures the geological structure of the underlying rocks, but is cut through in so many places as not to conceal it altogether. In spite of all the irregular crushing and the occasional concealment, many of the saddles and basins can be distinctly seen, or without great difficulty discerned, thanks to the mainly favorable circumstances.

In the Appalachian region of Pennsylvania the same influence of the geological structure upon the topography is observable on a much larger scale. The successive masses of harder and softer beds are much thicker, the whole series much stronger, stiffer and less readily yielding, and the basins and saddles much more extensive. The irregular crushing and breaking of these great folds is less in proportion to the whole, and the result is in the main an aggregation of comparatively simple regular waves, basins and saddles on a grand scale. The topography indicates those large forms in the same general way as the small ones we have been considering in the Punjab, and has been of great service in the study of the geology of Pennsylvania ever since the days of the first State Geological Survey. The varied topographical effects of the long, narrow basin-form and saddle-form were ably discussed by Lesley and H. D. Rogers forty years ago, when the subject was new to geologists. For the comparatively simple conditions of the Appalachians did not exist in most of the European regions where geological work had been done, and the outcrops of the different geological formations and their structure had been traced out more exclusively by means of their fossils, without regard to the topographical indications, that exist mainly in a less obvious degree.

The first impression was that the Pennsylvania topography had been produced by an immense flood of water, an ocean let loose, flowing over the land and carrying away vast quantities of earth and stones. In those days it was difficult to rid one's self of the idea that great geological changes were almost

instantaneously produced by tremendous cataclysms or even by downright supernatural means or miracles. The idea still lingers among men not familiar with geological matters that some stupendous topographical results have been effected in the twinkling of an eye by the "finger of God"—the expression cited by Prof. Branner. But all geologists now realize that the sculptured relief of the mountains and valleys, even where most astounding, even the gorge of the Niagara or the cañon of the Colorado, has been accomplished in the lapse of thousands of years by the same agents, chiefly rain and streams of water, that we see still in action about us.

It is plain that the geological indications given by the surface topography must have great value of a practical kind, and aid very much towards ascertaining both the general subterranean structure and the smaller details of either theoretical interest or economical importance. If coal or iron ore or other valuable mineral is known to occupy a particular geological horizon, a certain layer in a series of rock beds, such a series, for example, as we have in these Punjab illustrations, the place of outcrop of that horizon or layer, with the useful mineral, may in many cases be recognized merely by means of a careful study of the topography, and often the general structure, whether that of a basin or of a saddle, may be perceived; even though the surface of the ground may be so covered with loose earth and broken stone as to conceal the dips and precise character of the solid rock beds below.

The Punjab illustrations of the influence of the geological structure on the topography are interesting from their showing so clearly the small basins and saddles, with frequently very steep dips, but occasionally gentle ones, and with the repeated alternation of rather thin harder and softer rock beds, partly buried under level-bedded, soft, alluvium-like beds, in a region where the rock beds are in the main very strongly compressed and sharply folded and often broken and crushed together. The map is a striking example of the excellent geological results of faithful topographical work by surveyors who were no doubt quite unconscious of its having any significance for geology.

THE FRANKLIN INSTITUTE.

Annual Meeting, Wednesday, January 19, 1898.

TESTS OF THE SYNCHRONOGRAPH ON THE TELEGRAPH LINES OF THE BRITISH GOVERNMENT.

THE WHEATSTONE RECEIVER OPERATED BY THE ALTERNATING CURRENT IN TRANSMITTING INTELLIGENCE.

BY

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AND
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(*Concluded from vol. cxlv, p. 308.*)

DISCUSSION.

PROF. WILBUR M. STINE [Armour Institute, Chicago]:—Responding to your request to contribute to the discussion of the" Squier and Crehore Synchronograph System on the Telegraph Lines of the British Government," I shall briefly discuss the report in connection with the original paper presented to the American Institute of Electrical Engineers, April 21, 1897. Had the authors confined themselves to the strictly electrical engineering aspect of the investigations, the discussion would be scientifically more interesting and profitable. Since they lay more stress on the commercial application of their devices, the discussion is thereby considerably modified. A distinction should be made in the nomenclature of their system. According to their original paper, they worked a synchronous transmitting system in combination with a graphical receiver, of their own design. In the report just presented, the work of the authors is confined chiefly to a system of synchronous transmission of signals.

Their application to the physical principle of the rotation

of the plane of polarized light by a magnetic field of force of coincident lines was a laboratory experiment of great beauty and exceeding simplicity. Such a receiver is practically perfect in that the energy of the magnetic field may suffer rapid oscillations without sensible hysteretic and eddy-current losses. In this way the reactance of the receiver is purely inductive, with a practically constant co-efficient of self-induction, rendering it easy to compensate for the inductance by either distributed or localized capacity to any desired extent. This receiver places in the hands of the investigator a physical apparatus of great value.

The method of photographically registering the light transmitted through the magnetic field is, while satisfactory in the laboratory, of very doubtful applied value. The cost of the photographic plates, the time required for their development and transmission, combine to make a poor showing against the simplicity of the Morse and certain printing receivers. This portion of their device is properly a laboratory method. However, it is to be recognized that a laboratory method, however complicated, may, if commercial conditions favor and require it, be simplified and rendered practicable. At the same time, the train of receiving apparatus is too complicated to compete with a number of successfully-working receiving devices, and, judging from their report, the authors seem to have come to the same conclusion. It is this portion of their investigations which is marked with originality and possesses especial scientific interest.

In considering their system of synchronous transmission, it is apparent that the authors have merely made an application of the well-known and widely-used principles of the alternate current rectifier. Their experiment of operating an alternating current arc lamp taking ten ampères of current, while interesting of itself, shows their method contains nothing essentially new. This, however, is not in criticism of the applition with which they have experimented.

The chief difficulty in sending successive signals over a long land or submarine line consists in the character and value of the time-constant of the circuit. Such circuits contain both

distributed capacity and more or less variable inductance. Were it possible to make the time-constant of such circuits exceedingly small, they could be successfully operated at any speed of signal successions with any wave form, either of direct or alternating potential. But in practice the reduction and control of the time-constant is very difficult. This clearly indicates that there must be some particular electromotive-force wave form for maximum speed and sharpness of the signals transmitted, which will operate the circuit with the least possible resonance. Theory and practice both indicate a harmonic sinusoidal wave form, either alternating or pulsating, to fulfill these conditions. The chief merit of this report lies in the recognition and application of this fact.

No circuit-closing device, by reason of variable contact, can operate a line so as to maintain the reactance constant, Such devices are always faulty, and cannot operate a line with maximum speed and clearness.

The method by which the authors secure a rectification of the electromotive force wave is open to some criticism. For high-speed work the adjustment of the commutating strip and contacts must be exact, or the device is worse than a circuit-interrupter. The mechanical difficulties for securing this adjustment must be very great. The least inaccuracy of the perforations or the effect of moisture in the air, in causing unequal variations in the tape, would impair the adjustment. However, it is doubtless possible to provide mechanical corrections for those and other inequalities.

Drs. Edwin J. Houston and A. E. Kennelly:—The results reached by the experiments described in the paper; namely, that the effective speed of transmission with an alternating electromotive force was three times as great as with an electromotive force of the rectangular type, is a most interesting one. The great disparity, however, between the value of the electromotive force in the two cases somewhat invalidates the comparison; for, while the rectangular electromotive force is given as 100 volts, the sinusoidal electromotive force was 215 volts. Assuming the latter to be an effective value, its maximum was 304 volts, or about three times greater than

the rectangular. It is difficult to say how much allowance should be made for such a considerable variation in the electromotive force of transmission, but it would, probably, be quite considerable. Even making all allowances for this discrepancy, however, it seems remarkable that so great an improvement in speed should have been obtained with the sinusoidal electromotive force; for, while an improvement in speed had been predicted, theoretically, for the sinusoidal electromotive force as compared with the rectangular, the improvement expected was, probably, nothing like so great as that which is claimed in these experiments. It is interesting to observe that not only in the long-distance transmission of power, but also in the long-distance transmission of intelligence, the sinusoidal type of alternating electromotive-force wave is superior to more complex waves.

It is to be regretted that, for the purpose of comparison, the average linear insulation and the average linear inductance are not given in this interesting paper for the telegraphic lines on which the tests were conducted. While it may be true that the simple product of capacity and resistance gives, with sufficient accuracy for practical purposes, a numeric whose magnitude is inversely proportional to the speed attained, yet, it is not reasonable to suppose that the inductance and insulation have no effect upon the speed, whatever theory of transmission be adopted; whereas, according to the existing theory in general recognition, they have a very important influence which cannot be neglected when the ratios of inductance to capacity, and of conductor-resistance to insulation-resistance, are relatively so considerable as in the case of overhead telegraph lines.

It will be very interesting to ascertain what results may be found in practice with sinusoidal electromotive forces in transmission over submarine cables, in which the ratio of inductance to capacity and of conductor-resistance to insulation-resistance is relatively so small that the product of capacity and resistance is the true criterion of the slowness of transmission.

As regards the conclusion which the authors draw from the paper, that Government control and operation of the tele-

graph would be a benefit to the people of the United States because such control has proved advantageous in Europe, we think some doubt may be expressed, since the conditions are so different in the two countries. When Government Departments are operated by a personnel independent of political aims and influences, the proposition seems more likely to be worthy of assent.

PROF. R. A. FESSENDEN [Western University of Pennsylvania, Allegheny, Pa.]:—To the very natural gratification with which we learn of the brilliant success of this apparatus when put in competition with the most advanced system of the most advanced country (in this line) in the world, is added the more purely scientific pleasure of witnessing the triumph, at the first test, of a method developed upon sound theoretical principles over one which has had the advantage of years of assiduous experimental work.

What the outcome of the authors' labors may be cannot be at present foreseen. Here we certainly have an apparatus capable of fulfilling all demands upon it. As the writers point out, it can be quadruplexed, and it can also be used with different periodicities. Practically then, the capacity of a single wire may be considered infinite. The question then is, "Who shall put it to work?"

I believe it is a generally understood thing that the great telegraph companies do not want any improved apparatus. I have, at various times during the past ten years, been informed of this by men who were in a position to know, and whom I consulted with reference to improvements in such apparatus. It was stated that improvements would only be purchased when there was danger that they might lead to the formation of a competing company if not purchased. The fact that, though systems of rapid telegraphy have been in use for a long time in Europe, they have not been used to any extent in this country until recent years would seem to give some countenance to these statements.

The plan suggested by the authors, of a Government postal telegraph line, seems to be sufficiently feasible, proper and practical. There is no question of the vast benefit which has

resulted from the taking over of the telegraph by the British Government. Were it not for the ruinously low rate at which press messages are transmitted this system would be in a position to pay large dividends. There is no reason why we should continue to fall behind Europe in such matters.

The reasons for the assumption of such functions by the Government are many. No man can spend his waking hours in the continually enforced contemplation of the principle of the conservation of energy without appreciating the enormous losses which our present methods involve. The chief objection made is, that since we have so much corruption in politics with a given number of offices, we shall have much more if we create more. This always reminds me of Mark Twain's theory of the Mississippi, *i. e.*, that since, in a given number of years, the river had been shortening itself by cutting across bends at the rate of say twenty-miles per year, that in the year 2017, St. Louis would be a suburb of New Orleans. The real trouble at present is that we have not enough corruption, or, to state it more accurately, we do not give enough opportunity for corruption. We do not select our city governors from the beer saloons, because we have an especial admiration for the class, but because we are so well off and can receive so little immediate hurt from bad government that we take no interest in the thing. If the salaries of all employees in New York were fixed by the aldermen, only men of the best moral character would have any chance of election. It is, therefore, both for its direct and indirect benefits that the suggestion of the authors deserves to be carried out.

From the tests described, it is evident that we have now what may be called a perfect transmitter. It is doubtful if we shall ever improve it. The writer feels a slightly personal interest in the matter, as the advantage of using the sine wave in telegraphy was first pointed out by him (*Electrical World*, September 15, 1894). The apparatus mentioned therein (which is mistakenly given there as designed in 1891, as it was not until January, 1892) was, however, only designed for moderate speeds, on account of its mechanical construction, which necessitated the waiting after the key was pressed down for a pin on

a revolving shaft to engage, carry another pin through a definite part of a revolution and release it again, so that, whilst it got over the difficulties for which it was designed, it could never have been used in the manner in which that of the authors of the paper can.

When we have better receiving instruments we may expect even higher speeds with the authors' apparatus. The present instruments for receiving are defective in the following points:

(1) The ohmic resistance of the instrument is often very high. Since, as Heavyside has pointed out, its reactance should equal that of the line, and as it may easily be shown that its resistance should be as nearly zero as possible, its inductive voltage should equal the voltage drop on the line.

(2) At the position of rest, the co-efficient of self-induction should be less than one-fifth of the value when the moving part has made its stroke.

(3) The mark should always be made upon the return and not on the forward stroke, thus regaining all the energy stored up in the spring.

(4) The spring should be fastened on the moving part by a small crank, so that the acceleration of the spring may follow a sine square law. Unless this is done there will be always distortion, and the good effect of the sine wave will be partly nullified.

The sine wave has also a great advantage in the receiver, as well as in the line, as we can, with sine wave, so construct a receiver that there are no inertia losses. There is no doubt but that receivers much more sensitive than the syphon recorder can be devised.

I would join in congratulating the authors in their brilliant success, and hope we may soon see the system in commercial use.

Mr. A. V. Abbott [Chicago]:—The apparatus and the methods devised by Messrs. Crehore and Squier are certainly exceedingly novel and ingenious. Their experiments would seem to indicate that their apparatus was scientifically entirely feasible. There is but little question, I think, as to the opinion that improved facilities for rapidly transporting intelligence are in demand. There is no doubt but that if all our letters

could be sent by telegraph instead of by the slower process of the mails the community would reap an immense advantage, but there always comes in the commercial question as to whether facilities of this kind will pay, so that it seems to me the real point at issue concerning the synchronograph is the possibility of so simplifying and commercializing its operation as to make it available for the transmission of such matter as now occupies the mail bags of this country.

MR. PATRICK B. DELANY [South Orange, N. J.]:—I have read with much interest the report of Drs. Crehore and Squier relative to the tests of the synchronograph over some telegraph lines in England, in which it is claimed that the speed of the Wheatstone receiver was greatly increased by the use of sinusoidal alternations.

Without knowing what further light the discussion before the Institute may have thrown upon the results stated, I venture a few comments which will, I trust, be considered as subject to any revisionary effect that the discussion may have developed.

In the absence of any adequate specimens or fac-similes of the received record, however, it is hardly worth while to theorize on the cause of an unknown effect. In cable telegraphy, where the syphon recorder is used, there are four recognized degrees of legibility, viz.: "readable," "fair," "good," and "good enough for traffic," and the range between these limits amounts to about 50 per cent. of the speed. The same rule obtains within somewhat narrower limits in all recording systems.

In some of the tests reported, it is stated that certain "frequencies" were reached, and in others "messages were recorded with perfect clearness."

From the report it is difficult to determine whether the "frequencies" were simply rheotomic, and computed for word counting on the basis of thirty-six makes and breaks or half waves per word, or actual words. Pasting pieces of paper on a circuit wheel geared to or mounted directly upon the shaft of the generator can hardly be called telegraphy, or the machine a "synchronograph." It is synchronous in the same sense

that one end of a rigid shaft is synchronous with the other in its revolution. No one will deny that so far as "sparking" is concerned the Wheatstone and all other systems employing air gap contact-breaking devices would be improved if the circuit could always be broken at the time of no current, as it is proposed to accomplish by the synchronograph. This is of little or no consequence, however, where the air gap is dispensed with, and the transmitting tape is drawn between the contact points, as an arc cannot be formed to any injurious extent before it is brushed out by the paper. In fact, sparking is *prevented* in the first place by the burnishing effect of the transmitting tape on contact points meeting in the holes. It does not follow that, because the circuit can be broken at zero by pasting pieces of paper on a wheel mounted on the shaft of the alternator, or by using an endless band a few feet in length, the same degree of accuracy can be reached with various lengths of tape coming from numerous perforating machines having more or less imperfection in spacing. The play necessary for the sprockets of the feed wheel in the perforating machine and the transmitter, the drag put upon the tape by inertia of the roll of paper, or the friction of the contact fingers on the wheel of the transmitter, all combine to prevent synchronism between the perforations and the current waves.

And as any departure from absolute synchronism must result in false signals and the clipping of the regular ones, the difficulties in the way of applying sinusoids in practical telegraphy would seem to be a serious offset to any advantages possessed by the character of the current itself. With the Wheatstone receiver at least, transmission would have to commence from a standstill of the transmitter, it being necessary to begin each message or tape with the same polarity for marking, otherwise the polarized relay of the receiver would be reversed, while with a chemical paper receiver considerable confusion would result in translation unless the same course was followed. The construction of the signals on the receiving tape is a most serious objection, and involves a radical departure from legibility and accuracy. Ignoring the utterly impracticable proposition for the use of a *negative* record, the use

of two dots for a dash in the same line with the regular dots seems to strike at the foundation of efficiency, no matter what advantages sinusoidal currents might have as to speed or distance of working.

The record is the output, and a difficult one offsets all other considerations.

In the trials described in the report, with one exception the difference in speed and current pressure between the Wheatstone and the synchronograph transmitter seems to have been maintained in even ratio, the exception being the trial over the London-Aberdeen loop, $K\ R = 261{,}215$, in which forty-six words per minute with 100 volts is credited to the Wheatstone transmitter and 135 words per minute to the synchronograph transmitter with Wheatstone receiver at eighty-five volts. A specimen of the record would be especially interesting.

In the London-Aberdeen loop experiment without earth, $K\ R = 65{,}304$, the report states that "the synchronograph and chemical receiver *sent* at 'frequency' of 723," but that it was discovered that, with the loop broken at Aberdeen, the signals were received in London just the same. A specimen of this record submitted cannot be considered as the result of actual working over this circuit, but even though the signals had really passed around the loop, they certainly do not mark any advance in speed for simple alternations over a circuit of this kind at 200 volts or over.

As the dots shown in the specimen record are all in one line, it is to be assumed that the reversals were omitted in the arrangement of the pieces of paper on the circuit wheel of the transmitter or were eliminated from the record by using an electrode on top or beneath the chemical paper which left no record, thus recording alternate half waves, which, of course, has a clearing effect between the impulses. As this record claimed for the system was admittedly due to induction between the wires beyond Glasgow, it seems strange that, in a test over the same loop with the synchronograph and Wheatstone receiver, in which it is said 540 words per minute were "sent," this inductive effect is not mentioned. Signals composed altogether of dots could be correctly recorded on the

Wheatstone from inductive effects by simply reversing the relay, while signals might be recorded from leakage without reversal, the same as in the regular way.

It is to be regretted that specimens of the work claimed to have been done are not available, and that definite information regarding the transmitting and receiving apparatus has not been included in the report. It has been generally conceded all along that power transmission could be effected most efficiently by wave alternations, and that, over a circuit balanced to resonance, electro-magnets may be actuated by regular reversals at a higher rate than with currents put on and interrupted at full pressure and at irregular periods; but the application of alternations of regular periodicity to practical be recorded at a higher speed provided the tapes of ordinary telegraphic use can be made as synchronous with the generator as permanently-fastened pieces of paper mounted with mathematical precision on a circuit wheel. But, so far as chemical recording is concerned, even with this arrangement and impracticable character of receiving signals, there is no increase in speed shown.

An important factor affecting the speed results cited in the paper seems to have been overlooked in making comparison between the synchronograph and the Wheatstone systems computed on the basis of thirty-six half waves to the word. The synchronograph transmitter, in combination with the Wheatstone receiver, can only employ *complete* waves or their time equivalents at the receiving end, two in succession for a dash, one for a dot, one for the space between the different elements of a letter, two for separating the letters from each other, and three for spacing the words. The Wheatstone, having solid dashes, imposes no sacrifice of time or impulse for distinguishment of the dash from the dots, utilizing half waves for all spaces between the elements of a letter, one complete wave to space the letters from each other and two complete waves to separate the words.

Taking letter B, — - - -, for illustration, the synchronograph dash comprising two dots close together represents four half waves, then a space representing two, the first dot repre-

senting two, space two, second dot two, space two, third dot two, and four for spacing from the next letter, making a total of twenty half waves. The Wheatstone transmitter utilizing half waves for each space and dot with two extra after the last dot requires in all but fourteen half waves for this letter. Using the Continental Code, the synchronograph would employ 456 half waves in the transmission of the alphabet, while the Wheatstone requires but 294. Hence it will be seen that while a greater number of "frequencies" may be sent in a given time by the synchronograph, and some of them recorded, it does not follow that the speed of recording *letters* or *words* is raised in a proportionate degree. Furthermore, the excessive number of impulses necessary for the construction of letters requiring lighter and shorter contacts in order to make the time produces an impression at the receiving end proportionately small and faint, making translation exceedingly hazardous and slow, as is shown in the six letters submitted as a sample record. Compared with the ordinary Wheatstone impression, the difference is very striking.

The specimen record of "frequencies" recorded on chemical paper from synchronograph transmission over the London-Aberdeen loop, with no earth and 200 volts, at the rate of 1,446 alternations per second, was, according to the report, obtained with the loop broken at Aberdeen, which fact should have excluded it as an exhibit of speed rate; and, as already stated, it is hard to understand why the Wheatstone record over the same circuit and under the same conditions could have been free from the same induction effect to which the chemical record is attributed.

The chemical exhibit of "frequencies" shows dots but not from impulses of alternating polarity, the negative currents being omitted, nor is there anything to show whether these dots were the result of every second half wave or sent at comparatively long intervals, which, with a chemical receiver, would make a great difference in the record. A band of tape having one or two holes and drawn synchronously with the transmitter, or a circuit wheel arranged to send one or two impulses for each revolution would, with the chemical receiver moving suffi-

ciently slow to place these dots side by side, show a record very different from one made from transmission of *all* the impulses or half waves and the chemical tape moving fast enough to show them all plainly. With chemical recording, time plays a most important part. One volt will make a record over a line of 100 miles long if sufficient time is allowed at the receiving end for the weak and slowly-arriving current to have its full effect for electrolytic action between the iron-recording wire and the chemical tape; whereas, if the tape be drawn rapidly, no mark would be made over 100 feet of the same line. It would, therefore, be a mistake to suppose that impulses of short duration sent at intervals to a slowly-moving chemical receiver can be used as a basis for arriving at the speed at which successive or regularly alternating impulses without appreciable time between them can be recorded. In calling attention to this fact, no inference is suggested that this mistake was made, but absence of information as to the method of transmission beyond the paper pieces pasted on the generator wheel warrants this explanation of an effect which may not have been generally understood.

In any event, computation of telegraph speeds on the basis of "frequencies" of alternation having regular periodicity is most misleading. A chemical tape moving with speed necessary to record 723 "frequencies" per second over a circuit having $K\,R = 65{,}304$ would show a "tailing" mark from a single dot three inches in length if 200 volts were used. It is difficult to imagine how sinusoids of irregular time are to overcome this difficulty. The arrangement of signals made necessary by their employment would, I think, greatly aggravate the trouble even over the old style dot-and-dash-all-in-one-line plan. The true remedy lies in the employment of self-induction to reduce the tailing effect, and separation of dots and dashes into different lines, so that what tailing is left may be disregarded.

ELECTRICAL SECTION.

Stated Meeting, November 23, 1897.

THE BOOSTER SYSTEM AS APPLIED TO ELECTRIC RAILWAYS.

BY J. LESTER WOODBRIDGE.

The name "booster," a somewhat significant if not very euphonious term, was coined, I believe, by Mr. Wm. S. Barstow, of the Brooklyn Edison Illuminating Company, who was one of the pioneers, if not the pioneer, in the practical application of this system to electric lighting. The word has gradually come to mean any electro-magnetic generator whose armature is connected in series with a transmission conductor or feeder with the object of compensating for the loss of voltage in that conductor due to the current which it is transmitting. As this loss of voltage or drop is proportional to the current, it is evident that, in order to compensate for it exactly, the voltage of the booster must vary in a similar manner; that is, it must rise and fall with the load. If this variation of load is gradual, or the short period fluctuations small, the booster voltage may be hand regulated. But in railway work, unless the fluctuations are taken by an outlying storage battery or other power plant, this is never the case, and it is found necessary to employ the series-wound booster, or what I have called the compound-series machine, giving the series effect, the voltage of the machine varying automatically with the load.

The typical arrangement of booster is shown in *Fig. 1*, *A* being the positive bus and *B* the negative, which are supplied with electric current by the generators *X* and *Y*. *Z* is the booster, connected at its negative terminal to the positive bus, and at its positive terminal to the feeder whose voltage is to be raised. This feeder supplies the distant section of the line *C E*, being tapped into it near its middle point at *D*, whence it feeds in both directions.

The nearer section of the line *A C* is fed directly from the

bus bars, and it is usual, though not always necessary, to insulate these two sections from each other by the section insulator *C*. If this is omitted, there might be danger of overloading the booster. In fact, the path *F D C G* would apparently constitute a short circuit, but its resistance is generally too great to allow the machine to build up without a load on the line. Where it is practicable to do so, it is a good plan to omit this section insulator. This will tend to steady the load on the booster and the voltage at *D*.

The aim is, of course, to maintain the point *D* at station voltage. For several reasons, which will be noted hereafter, this cannot always be accomplished exactly. The voltage here is liable to fluctuate, but the fluctuations can be brought within allowable limits by properly designing the installation, and the average voltage can be brought to that of the bus bars.

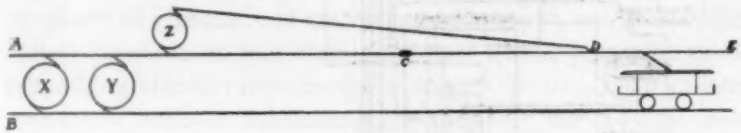


FIG. 1.

The effect, therefore, is about the same as if there were another power-house, rather poorly regulated, situated at *D*.

In *Fig. 2* I have shown the connections of what I have alluded to as a compound-series booster. This is simply an ordinary compound-wound constant-potential machine, connected up so as to get the series effect from both the series and the shunt windings. If the connections in this diagram be followed out, it will be seen that when the double-throw booster switch is thrown down the machine is connected up as an ordinary generator. When it is thrown up, and the machine is in use as a booster, the entire current of the boosted section passes from the positive bus bar through the armature and the series winding; and the shunt coils are connected in parallel with each other and with a certain portion of the feeder, so that a small but constant percentage of the current is diverted through them and their magnetizing force like that of the series winding is proportional to the load. Such an arrangement permits of the use of a regular railway generator as

a booster when required, while at other times it may still be employed as a generator.

The booster system is one of several remedies available for the treatment of the aggravated cases of low line voltage with which nearly every electric road has had to contend at one time or another.

The first and most obvious remedy for such cases is more copper. But, as the distance of transmission is gradually ex-

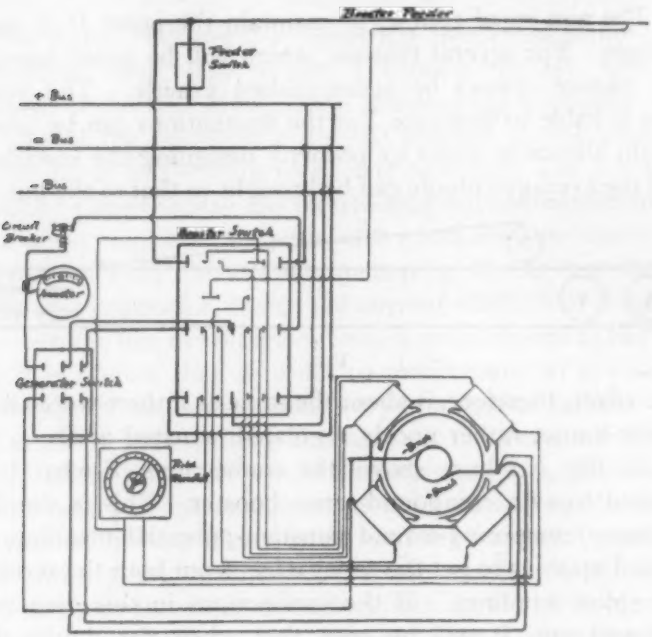


FIG 2.

tended, the cost of copper necessary to carry the maximum current becomes a very serious item, increasing, as it does, with the square of the distance, and even more rapidly as soon as the track drop becomes appreciable, until finally this feeder cost becomes so great that some other solution is sought. For this question of transmission loss must be considered from two quite different aspects, first, that of economy; second, that of practical operation. The first deals with average conditions, the second with maximum conditions. Considerations

of economy dictate that when a feeder system is so proportioned that the cost of the energy loss in every section of it, for a year, say, is equal to the interest on the copper investment for that section for the same length of time, the most economical arrangement has been reached, and it will not pay to add more copper.

This reduces to the law that for best economy the average drop in volts per mile of conductor should be the same throughout the entire system regardless of distance. But from the standpoint of practical operation we know that, regardless of economy, we must maintain the voltage on all parts of the system above a certain minimum under the worst conditions of load. This consideration not only leads to a different distribution of copper from that just given, but, where the load reaches occasionally a maximum many times its average value, or where the distance of transmission is great, we must either install far more copper than economy would prescribe or do something else to maintain the voltage. In fact, most railway managers, without calculating the dividing line exactly, have come to realize in a general way that it will not pay to put up the amount of copper necessary to carry satisfactorily the occasional emergency loads which they are called upon to provide for. An additional power-house is sometimes the solution, though in most cases this is out of the question, and the tendency in general is rather toward concentration of plant. In the great majority of cases, the booster system will be found to meet the requirements exactly, especially when machinery already on hand can be utilized, as has been the case in the installations with which I have been personally connected.

Deferring the consideration of economy for the present, I will first take up a few points on the question of operation. From this standpoint the object of the booster is to maintain station voltage, as nearly as possible, at a distant point on the line. This, as I have intimated above, cannot be done exactly, the variations being due to the following causes, inherent in the booster machine, viz.:

(1) Saturation of the field magnets.
(2) Sluggishness, due to inductance and Foucault currents.
(3) Hysteresis.

The manner in which the first of these would interfere is very evident. If the resistance of the circuit is one ohm, the booster should give 100 volts under a load of 100 ampères and 200 volts under a load of 200 ampères, etc., whereas it will not do this exactly, but if, at 200 ampères, the fields have begun to be saturated, the voltage will be somewhat less than 200. In designing a new machine, this deviation can be reduced within almost any assignable limits by putting plenty of iron in the magnetic circuit. In utilizing a machine already on hand, however, we must either limit the load or provide sufficient copper in the feeder to limit the maximum voltage required, and, therefore, the range of magnetization. That is, if when the machine is built up, say to 300 volts, the saturation curve begins to deviate as far as is permissible from a straight line, we must limit the product of the feeder resistance by the maximum ampères to this amount, 300. The deviation due to this cause can be averaged over the whole range of load by making the machine build up under light loads a little higher than necessary, so that under the heavy loads it will not fall off so much, and, as a considerable range of voltage is not objectionable in railway work, this variation can readily be brought within permissible limits.

The effects of sluggishness due to Foucault currents and to the high inductance of the shunt fields, when these are used, are rather more serious. While the drop in the line responds instantly to changes of current, the changes in the voltage of the machine are more or less gradual. When the shunt fields are connected in parallel with a certain portion of the feeder, it requires an appreciable time for the current in them to rise to the full strength corresponding to an increase in the current in the feeder; moreover, the eddy currents set up in the iron by reason of a change in magnetism tend to retard such change. Lamination of the field cores largely eliminates the latter effect, while the former may be limited by limiting the extent to which the shunt fields are utilized. If they give but a small proportion of the magnetizing force, it will be only that portion that will lag. Their inductance, too, is reduced by dividing the whole shunt winding into as many sections as pos-

sible, and connecting these in parallel with each other when boosting.

As a result of this sluggishness of the booster, we find that whenever the load suddenly drops the voltage on the line will jump above the normal and then fall back, the high voltage of the machine persisting for an instant after the drop in the line has disappeared. Conversely, when the load is thrown on suddenly, the voltage first drops because the drop in the line is first felt, and then rises to the normal again as the machine builds up.

The effects of hysteresis are very similar to those just described, but are of little importance in railway work, owing to the peculiar nature of the variations of load. The booster will, of course, show a higher voltage with a falling load than with a rising load of the same amount, and this difference will often amount to fifty or seven-five volts. But a moment's consideration will reveal the fact that in railway work we are almost invariably dealing with a falling load, and can, therefore, figure on the upper curve of the hysteresis loop. For when the current used on any car is shut off it is usually shut off entirely, which would mean a falling load on the booster; and when the current is turned on or increased by the controller it rises instantly to a maximum, and at once begins to fall off as the speed of the car increases, and again we have a falling load on the booster. It is only when a car passes from a lighter to a heavier ascending grade without any accompanying change of the controller that the condition of rising load exists, and this only until its controller or that of some other car on the line is changed. So the curve of rising magnetization can be practically ignored.

In illustration of the foregoing points I have prepared a few diagrams giving the results of voltage readings taken on some of the boosted lines with whose installation I have been personally connected.

Fig. 3, drawn from memory, gives an approximate idea of the map of one of these lines, and is worthy of a moment's comment, as the arrangement differs from the typical one shown in *Fig. 1*, in that the booster feeder was bifurcated at *B*. It will

be noted that these two branches, *B C* and *B D*, are comparatively short, and this is about as far as it is practicable to carry the attempt to boost two lines with one machine. In order that the voltage at the points *C* and *D* should be maintained as nearly as possible the same in spite of any unequal distribution of load, they were connected not only by the trolley wires but by heavy feed wire. The booster feeder is in two parts all the way back to the power-house, so that by means of a switch at *K* and another on the switchboard either line can be disconnected from the booster and fed directly from the bus bar while

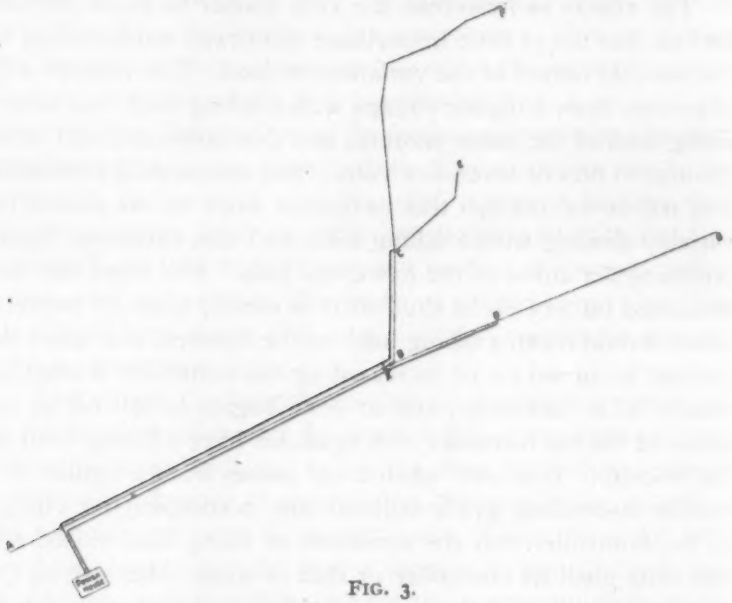


FIG. 3.

the other is boosted, the voltage ratio of the booster (*i. e.*, the ratio of volts to ampères) being at the same time increased to correspond with the increased feeder resistance by means of the rheostat in the shunt-field circuit.

On a day of extremely heavy traffic, voltage readings were taken at the point *F* eight miles from the power-house, and I have incorporated a series of these readings in *Fig. 4*. The machine used in this case is a G. E. 500 K. W. four-pole belt-driven generator, and is only moderately sensitive to

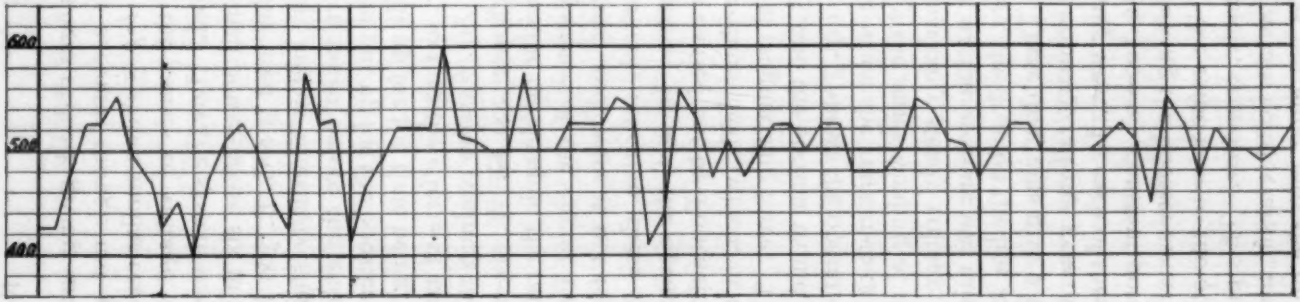


FIG. 4.

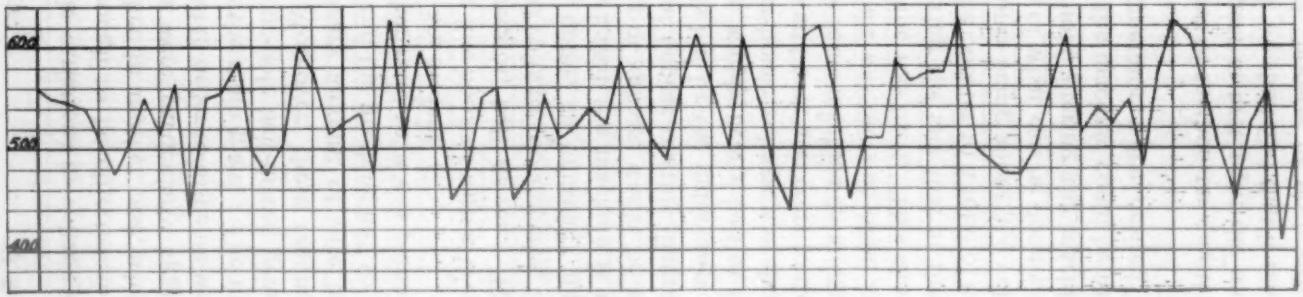


FIG. 5.

changes of load, giving considerable variations in voltage on this account, though not great enough to be objectionable.

Fig. 5 shows similar readings taken in another case, where all the causes of voltage variation were particularly aggravated. Here the system was installed in order to dispense with a small power-house six miles from the main plant. The machine used is a G. E. 300 K. W. four-pole belt-driven generator, and is unusually sluggish. Moreover, these readings were taken before the entire necessary amount of wire had been put up for the booster feeder, and the machine had to be built up for the time being in a higher ratio than was planned for, so that the effects of saturation are evident.

Fig. 6 shows readings taken on a line boosted with a Westinghouse 200 K. W. six-pole generator, belt driven. This machine builds up in the ratio of 170 volts to 100 ampères, the resistance of the circuit being 1·7 ohms, an unusually high figure, and, were it not for the fact that the machine is remarkably sensitive, these variations of voltage would be excessive. In fact, the deviations that appear on this diagram are caused not by Foucault currents but by the inductance of the shunt fields, which, in this case, supply nearly half of the total magnetizing force. The power-house voltage was about 525, and the booster would at times add over 400 volts to this.

Fig. 7 shows the operation of the same machine on another line when the resistance of the circuit was but one ohm, and only the series winding of the machine was used. This shows remarkably steady voltage, considering the fact that at times the station pressure was raised by the booster to a total of 850 volts, the drop on the line at such times being about 350 volts.

These diagrams give a fair idea of what can be done with an ordinary railway generator, without altering the machine in any way. In each of these cases the machine could be used as a 500-volt constant-potential generator when desired by throwing the booster switch.

We come now to the other aspect of the booster question, namely, economy. This might appear at first sight the most important consideration, but I think we shall find that it really does not enter into the question of "booster or no booster"

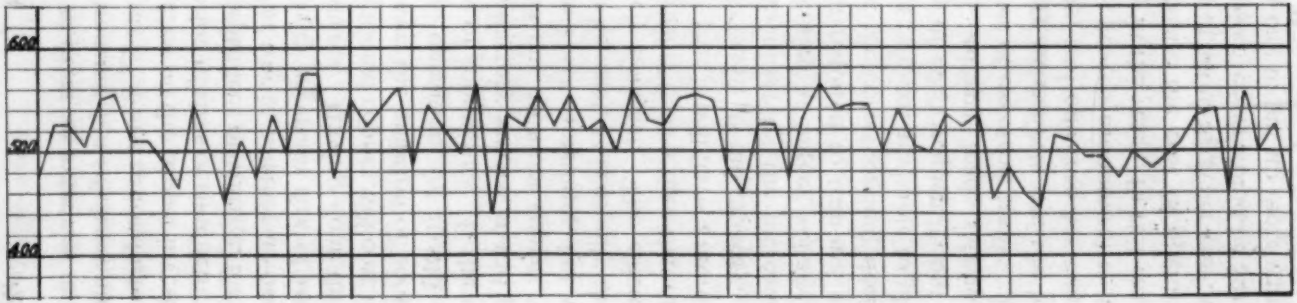


FIG. 6.

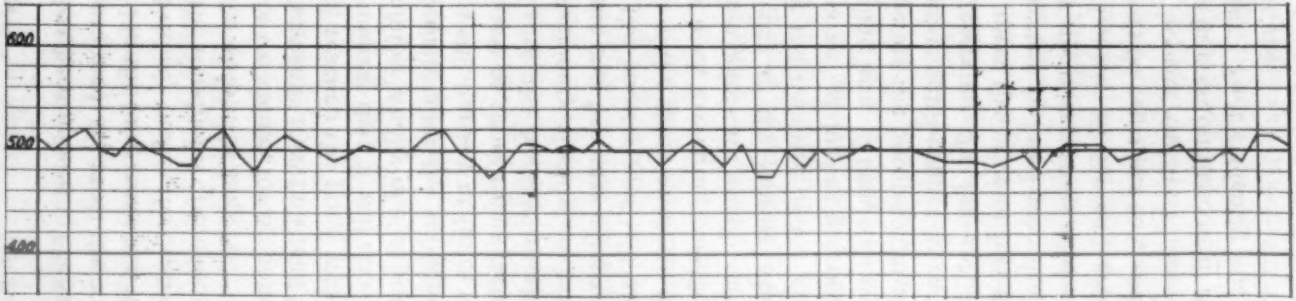


FIG. 7.

to so great an extent as might at first be supposed. The law of transmission efficiency already mentioned, viz.: that the cost of the $C^2 R$ loss in conductors should in the long run equal the interest on the copper investment obviously makes the determination of sizes of conductors, from the standpoint of economy, independent of voltage, for any given output in ampères. In other words, whether we boost or not we should, for economy, put up a certain size of feeder to transmit a certain load in ampères. Having done this, having reached the point where additional copper will cost more in interest than it will save in power, the question of boosting is almost wholly one of practical operation, for it will not materially alter the economic size of conductors. If the voltage is still too low at times for satisfactory service, it will pay to boost at those times rather than put up more copper. To be sure, the booster installation costs something, but where machinery already on hand can be used, as is usually the case, the cost becomes comparatively nominal. The efficiency of the booster unit will also probably be less than that of the rest of the plant, owing to the fact that it will have a more variable load, averaging considerably below its full capacity. But these points are usually more than offset by the increased efficiency of the motors when operated at higher voltage, and by the decrease in the current required to transmit a given power at higher potential, and the corresponding decrease in line loss. Then, too, it is as a rule not advisable to plan to operate the booster continually or even frequently, but to put up enough copper to carry the ordinary loads satisfactorily, reserving the booster for times of excessive traffic. But the lower the price of fuel the more extensively can the booster system be used with economy, and one case has come under my observation where it has proven economical to run the booster all day and every day in the year. In this case fuel costs 60 cents per ton, and I estimate the cost of operating the booster eighteen hours a day at about $196 per year, while the interest on the cost of the booster feeder would be $216 per year. So it evidently would not pay to put up more wire on that line.

When the booster is used only a few times a month, and

then for only a few hours, as is usually the case, the question of economy is so obviously unimportant that it is hardly worth while to reduce it to exact figures, except as a matter of curiosity.

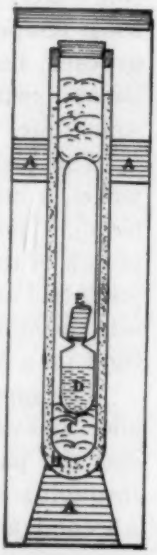
CHEMICAL SECTION.

Stated Meeting, Friday, March 15, 1898.

On a Supposed Change of Weight with Change of Temperature.

By Paul R. Heyl, Member of the Institute.

Certain experiments performed by the writer during the past summer seemed to indicate that the loss of weight noticed in weighing hot bodies was not entirely to be accounted for by the rarefaction of the surrounding air, but that there might be a true loss of weight of minute proportions. To settle this point, the following apparatus was devised, a sectional view of which is shown in the accompanying cut:



The outer case consisted of a flat-bottomed glass cylinder made from a piece of tubing. It was 4·5 centimeters in diameter and 17 centimeters high. Within this was supported, by pieces of cork, *A*, a jacket made from two test tubes. The diameter of the larger tubes was 2 centimeters, and the space between the walls of the jacket about 2·5 millimeters. The jacket was 14 centimeters high over all. The space between the walls contained glacial acetic acid, *B*, and the test tubes were held together by a ring of cork between them at the mouth, which ring was cemented air-tight by a mixture of rosin and beeswax. The jacket with its contents could be lifted out of its cork supports whenever desired.

A little bomb for generating heat was constructed as follows: A piece of glass tubing of such diameter as to slip easily inside the jacket was choked by heating and pressing upon a three-cornered file. By this means the bore of the tube was

sharply reduced at one point to a slit about 2 millimeters wide. The choked tube was sealed off about 1·5 centimeters below the choke, and in the lower chamber thus formed was placed dilute sulphuric acid, *D* (half water by volume). Holding the tube upright, a lump of caustic potassa, *E*, was dropped in, which was arrested at the choke. Still keeping the tube upright, it was sealed off some 2 or 3 centimeters above the potash.

The acetic acid in the jacket was now frozen. This substance when pure is said to freeze at 16·7° C., but I have never been able to obtain any of a higher melting point than 15° C. It exhibits surfusion to an excessive degree, so that to start the solidification it is necessary to use a mixture of ice and salt. Solidification once started can be completed by a stream of cold water. The melting point of the acid is not far below the usual temperature of a room, and the jacket is not directly exposed, but protected in the packing case by an air-jacket about 1 centimeter thick, so that the solid acid can be kept for some time.

The prepared bomb was dropped within the acetic acid jacket, a little cotton, *C*, being placed beneath and above the bomb. The opening of the inner test tube was corked, and the mouth of the outer packing case closed by a flat cork, whose pores had been stopped with paraffin, and which was cemented into the mouth of the tube by means of paraffin, so as to be air-tight for a moderate increase of pressure.

The apparatus thus prepared was counterpoised upon a balance, and when equilibrium was attained the beam was lowered and the pan arrests set. The apparatus was now grasped through a handkerchief, removed from the pan, held inverted a second, and then replaced in its former position. The beam was again raised, the pan arrests released, and the swinging of the pointer noticed.

In all cases some trifling displacement of the zero point was observed, but so small as to be far less than the limit to which the balance could be trusted with the great load of the apparatus (140 grams) upon it. With this load the balance used could not be trusted to give concordant weighings beyond the third decimal place.

The result is entirely negative, but is of value in so far as it

enables us to assign by direct experiment a superior limit to any change of weight due to change of temperature. It might be interesting to repeat this experiment with a balance sufficiently large and delicate to carry the weighings a couple of decimal places further. It seems hardly credible that if gravitation is a property of matter it should be unaffected by the state of the matter. The first step towards an explanation of gravitation will have been made when it shall be shown that gravitation depends even in the slightest degree upon something else than the relative positions of bodies.

THE ZEUNER DIAGRAM.

By William Fox,
Assistant Professor of Applied Mathematics.

Professor Peabody, in his book on valve gears, makes the following statement: "Zeuner's diagram does not admit of the use of the lead in solving problems that arise in designing valves, but we may use instead the lead-angle." (Page 16.) Professor Spangler, on the other hand, states, on page 157 of his book, that no other diagram "is as convenient as and none more accurate than the Zeuner diagram." As a matter of fact, he solves Problem IV, involving lead, *exactly* by means of the Zeuner diagram, and only *approximately* ("by trial") by means of Bilgram's method.

In order to prove that there are no problems incapable of an exact geometrical solution by means of the Zeuner diagram, we shall first enumerate all the problems possible.

Let r = eccentricity = $C\ E$ (*vide. Fig. 1*).
l = lap (outside) = $C\ P$.
l' = exhaust lap (inside).
p = port-opening (maximum) = $P\ E$.
i = lead = $A\ L$.
i' = exhaust lead.
β = 90° — advance angle = $E\ C\ L$.
α = angle whose versine is ratio of cut-off = $K\ C\ L$.
α' = exhaust cut-off angle (compression or cushion).
η = lead-angle (pre-admission) = $L\ C\ M$.
η' = exhaust-lead-angle (release).

There will be two sets of problems, one set involving the quantities r, p, l, i, β, α, η, and the other set, the quantities r, l', i', β, α', η'. If we solve only one of these sets of problems, the others can of course also be solved in the same manner.

We have, from the diagram, the following equations:

$$p = r - l \tag{1}$$

$$r \cos. \beta - l = i \tag{2}$$

$$r \cos. (\alpha - \beta) = l \tag{3}$$

$$\beta = \frac{1}{2}(\alpha - \eta) \tag{4}$$

These equations involve seven (7) quantities; hence if any three quantities are given the other four may be found. The only exceptions are the data r, p, and l, and the data β, α, η, from which it is evident no other quantities can be found.

Making the required combinations of three quantities, we obtain the following problems:

Problem (1) given r l β, to find the others.
(2) given r l α, to find the others.
(3) given r l i, to find the others.
(4) given r l η, to find the others.
(5) given r i β, to find the others.
(6) given r i α, to find the others.
(7) given r i η, to find the others.
(8) given r and any *two* of α β η, to find the others.
(9) given l i α, to find the others.
(10) given l i β, to find the others.
(11) given l i η, to find the others.
(12) given l and any *two* of α β η, to find the others.
(13) given i and any *two* of α β η, to find the others.
(14) given p i β, to find the others.
(15) given p i α, to find the others.
(16) given p i η, to find the others.
(17) given p and any *two* of α β η, to find the others.

We omit problems involving p and l, or p and r, as they are identically with data r and l (Problems 1 to 4).

SOLUTIONS.

Problem 1.—The construction gives at once (*vide Fig. 1*) the points *A*, *B*, *P*, *E*, *L*, *D*, and the solution is evident.

Problem 2.—Given points *C*, *B* and circle *X X* through *K* with radius *r*. A line through *B*, perpendicular to *B C*, will intersect the circle *X X* in point *E*.

Problem 3.—Given points *C*, *A*, and *L* and circle *X X*. A line through *L*, perpendicular to *C L*, intersects the circle *X X* in point *E*. The circle *C B E D* (diameter $= C\ E = r$) gives the other important points.

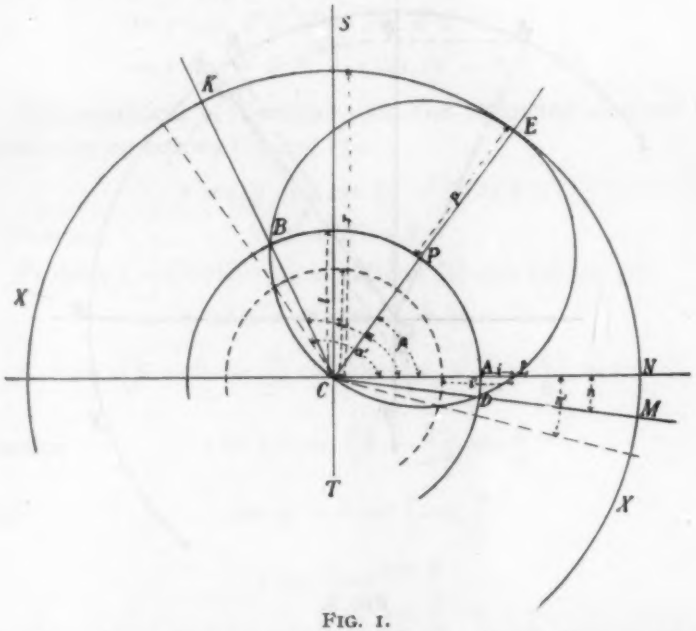


FIG. 1.

Problem 4.—Given points *C*, *A*, and *D* and circle *X X*. To find *E*, we must draw through point *D* a line perpendicular to *C D*, intersecting circle *X X* in point *E*.

Problem 5.—Given points *C*, *E*. The circle on *C E* as diameter cuts the line *C N* in point *L*. Measuring off distance $i = A\ L$, gives point *A* and consequently the lap circle.

Problem 6.—This is one of the problems involving the lead *i*, and is somewhat more difficult of solution, because we have

to combine equations (2) and (3) and eliminate β, in order to find the value of l in terms of r, i, and α.

Given (*vide Fig. 2*) point C, circle $X\ X$, and points K and N. Draw the line $S\ T$ perpendicular to $C\ N$; project the point K on line $S\ T$ giving point O; bisect the angle α ($K\ C\ N$) by the line $C\ R$; lay off $C\ I = i$ (lead) below C if i is positive or above if the lead is negative; through I draw a line parallel to $C\ R$ and cutting a circle, radius $C\ O$ and centre C, in the point

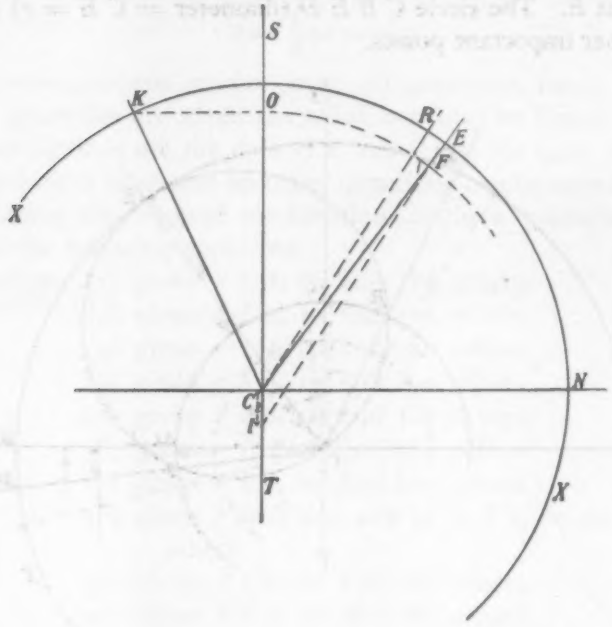


FIG. 2.

F. Then will the line $C\ F$ produced pass through point E, thus giving the angle $E\ C\ N = \beta$.

Proof: $$C\ O = C\ F = r\ sin.\ a$$

$$< C\ I\ F = < O\ C\ R = 90° - \frac{a}{2}$$

In the triangle $C\ I\ F$,

$$\frac{\overline{C\ I}}{\overline{C\ F}} = \frac{sin.\ C\ F\ I}{sin.\ C\ I\ F} = \frac{sin.\ F\ C\ R}{sin.\ (90° - \frac{a}{2})} = \frac{sin.\ F\ C\ R}{cos.\ \frac{a}{2}}$$

or, $$\frac{i}{r \sin. a} = \frac{\sin. F C R}{\cos. \frac{a}{2}}$$

or, $$i = r \sin. F C R \frac{\sin. a}{\cos. \frac{a}{2}} = r \sin F C R \frac{2 \sin. \frac{a}{2} \cos. \frac{a}{2}}{\cos. \frac{a}{2}}$$

$$= 2 r \sin. F C R \sin. \frac{a}{2}$$

$$= r \left\{ \cos. \left(\frac{a}{2} - F C R \right) - \cos. \left(\frac{a}{2} + F C R \right) \right\}$$

$$= r (\cos. F C N - \cos. F C K)$$

$$= r \cos. F C N - r \cos. (a - F C N)$$

This equation is identical with the following derived by combining equations (2) and (3):

$$r \cos. \beta - r \cos. (a - \beta) = i \qquad (5)$$

Hence, $< F C N = \beta$

Problem 7.—Combining equations (4) and (5) we get

$$r \cos. \beta - r \cos. (\beta + \eta) = i \qquad (6)$$

or $$r \cos. \left(\overline{\beta + \frac{\eta}{2}} - \frac{\eta}{2} \right) - r \cos. \left(\overline{\beta + \frac{\eta}{2}} + \frac{\eta}{2} \right) = i$$

whence $$i = 2 r \sin. \left(\beta + \frac{\eta}{2} \right) \sin. \frac{\eta}{2}$$

now $$\sin. \eta = 2 \sin. \frac{\eta}{2} \cos. \frac{\eta}{2}$$

or $$2 \sin. \frac{\eta}{2} = \frac{\sin. \eta}{\cos. \frac{\eta}{2}}.$$

hence $$i = \frac{r \sin. \left(\beta + \frac{\eta}{2} \right) \sin. \eta}{\cos. \frac{\eta}{2}}$$

or $$\frac{i}{r \sin. \eta} = \frac{\sin \left(\beta + \frac{\eta}{2} \right)}{\left(\sin. 90° - \frac{\eta}{2} \right)} \qquad (7)$$

From this we readily get a solution similar to that of Problem 6.

Given (*Fig. 3*) point C, circle $X\ X$, and points N and M. Draw $S\ T$ perpendicular to $C\ N$ and project point M perpendicularly on $S\ T$ to point Q. Bisect the angle $\eta\ (= M\ C\ N)$ by the line $C\ R'$. Lay off $C\ I' = i$ (lead) on $C\ S$, and through point I' draw a line parallel to $C\ R'$ and cutting a circle, radius $C\ Q$, centre C, in the point F'. Then will the line $C\ F'$ produced intersect the circle $X\ X$ in point E, making the angle $E\ C\ N = \beta$.

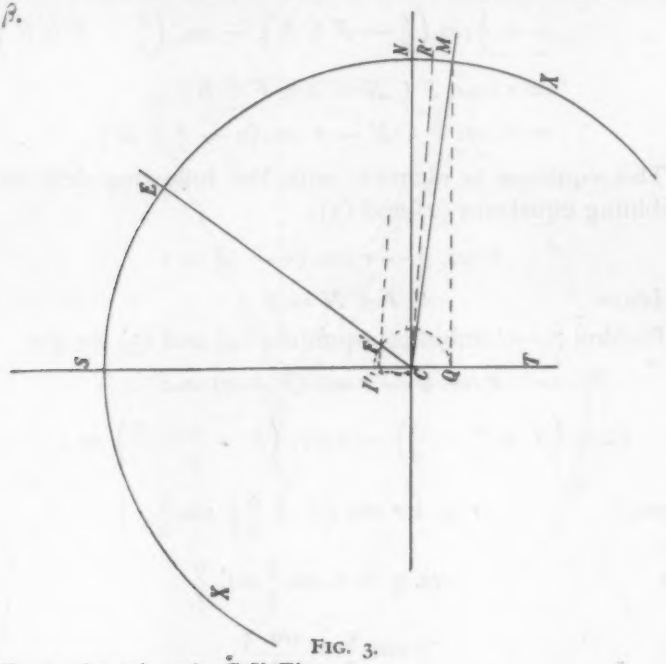


FIG. 3.

From the triangle $C\ I'\ F'$

$$\frac{C\ I'}{C\ F'} = \frac{sin.\ C\ F'\ I'}{sin.\ C\ I'\ F'} = \frac{sin.\ C\ F'\ I'}{sin.\ Q\ C\ R'}$$

or

$$\frac{i}{r\ sin.\ \eta} = \frac{sin.\ C\ F'\ I'}{sin.\left(90° - \frac{\eta}{2}\right)}$$

This is identical with equation (7), and, therefore,

$$< C\ F'\ I' = \beta + \frac{\eta}{2} \text{ and } \beta = C\ F'\ I' - \frac{\eta}{2} = F'\ C\ R' - \frac{\eta}{2}$$
$$= F'\ C\ N$$

Problem 8.—Given points C, N and circle $X\ X$ around

center C. Any two of the points M, E, and K being given, the third one is found immediately by observing (Eq. 4) that $M\,E = E\,K$.

The circle $C\,B\,E\,L\,D$ being drawn on $r = C\,E$ as a diameter, the points of intersection with the given lines $C\,M$ and $C\,N$, and $C\,K$ will give the other quantities required. (*Fig. 1.*)

Problem 9.—Given (*Fig. 1*) point C and lap circle and line $C\,B$ giving point B; also distance $A\,L = i$ gives point L. At L erect a perpendicular to the line $C\,L$, and at B a perpendicular to the line $C\,B$. The intersection of these perpendiculars will be the point E.

[*To be concluded.*]

ANNUAL REPORT OF THE DIRECTOR OF THE DRAWING SCHOOL OF THE FRANKLIN INSTITUTE, FOR THE SESSIONS 1897–1898.

The number of pupils this year has been just about the same as last, which, considering the generally disordered condition of the building due to the alterations, is as good as could be expected. The regularity of attendance has been very good, and there were few who did not maintain their interest and industry to the end. The Architectural Class has been particularly enthusiastic. Almost the entire school has been composed of young men actually engaged in work or business, where a knowledge of drawing is requisite, or at least desirable, and, consequently, there has been very little idleness or trifling, but a persistent effort to make the most of the opportunity. This is very commendable, because it is not recreation, but work, and work under disadvantages. Daylight is none too good for first-class drawing, and artificial light is at best very trying for fine and accurate work, and when this work must be done in hours supposed to be devoted to rest or pleasure, it is rather surprising that more do not fall out of line early in the season.

The utility and importance of the study for all those engaged in mechanical industries is the secret, and it speaks well for our industrial future that so many young men are willing to devote two evenings of every week to their improvement of their technical knowledge.

It is gradually being realized by industrial concerns that thoroughly detailed drawings, with everything well thought out as to materials, finish and special characteristics, not only greatly expedite work but also reduce its cost. Perfect clearness and certainty of the meaning of drawings require a higher grade of ability to produce and cost more money, which, however, is sure to prove a good investment.

Every hour spent in the drawing office on the design, dimensions and classifications of the details, is worth three in the shop, if they have to be looked up there. And these things, when properly recorded on the drawings, are done for all time, while if left to the foreman and mechanics, they have to be repeated every time the work is done. But to become capable of doing them well the draughtsman must get all the shop experience possible, by

actual work if he can, or by observation if he must. Much of the hustle and bluster seen in many shops is due to the fact that many men are required to attend to things outside their province, which have been neglected by the draughtsmen.

The purpose of this school is to give a start in the right direction to the pupils, in order that they may eventually acquire the ability to fill this need, and this purpose has been kept steadfastly in view, and will so continue.

WM. H. THORNE, *Director.*

THE FOLLOWING STUDENTS ARE ENTITLED TO HONORABLE MENTION :

In the Senior Mechanical Class.

Louis Snyder, Carl A. Dannerth,
George W. J. Stout, Adam Frazer,
Harry V. Walker.

In the Intermediate Mechanical Class.

H. C. Brinton, Alexander Stevenson,
Charles P. Richter, Joseph Bourgeois.

In the Junior Mechanical Class.

Kotaro Omakato, R. Patterson,
William Bucher.

In the Architectural Class.

John H. Lippincott, Jr., Charles Ritzel,
George Smith, J. A. Kirkpatrick.

In the Free-Hand Class.

Charles T. Greene, George F. L. Linderman,
Robert F. Plum.

The following students are awarded SCHOLARSHIPS from the B. H. Bartol fund, entitling them to tickets for the next term :

Fritz H. Larson, Harry Thompson,
John Kleisch, George Eiselé,
Alfred Whitney, Jr.

The following students, having attended a full course of four terms, with satisfactory results, are awarded CERTIFICATES :

George H. Bardsley, Joseph McGovern,
Benjamin Bramin, Berthold Reibrich,
Adolph K. Bottke, Warren W. Rice,
Carl A. Dannerth, Ivan Schultz,
George Eiselé, Louis F. Snyder,
Howard Fryling, Russell Stapler,
William M. H. Jones, Rupert Tricker,
James Keating, Harry V. Walker,
Henry Wolf.

And from the Branch School :

Alva H. Bewley, Jesse H. Weiss, Harry Robson.

NOTES AND COMMENTS.

REMOVING RUST FROM IRON ELECTRICALLY.

A simple and effective way of clearing rusted iron articles, no matter how badly they are rusted, consists, according to Carl Hering, in attaching a piece of ordinary zinc to the articles and then letting them lie in water to which a little sulphuric acid is added. They should be left immersed for several days, or a week, until the rust has entirely disappeared, the time depending on how deeply they were rusted. If there is much rust a little sulphuric acid should be added occasionally. The essential part of the process is that the zinc must be in good electrical contact with the iron; a good way is to twist an iron wire tightly around the object and connect this with the zinc, for which a remnant of a battery zinc is suitable, as it has a binding-post. Besides the simplicity of this process, it has the great advantage that the iron itself is not attacked in the least as long as the zinc is in good electrical contact with it. When there is only a little rust a galvanized iron wire wrapped around the object will take the place of the zinc, provided the acid is not too strong. The articles will come out a dark gray or black color, and should then be washed thoroughly and oiled. The method is specially applicable to objects with sharp corners or edges, or to files and other articles on which buffing wheels ought not to be used. The rusted iron and the zinc make a short-circuited battery, the action of which reduces the rust back to iron, this action continuing as long as any rust is left.—*Electrical World.*

DEATHLY ELECTRIC SHOCK.

The cause of death by electric shocks has been experimentally investigated by Prof. T. Oliver and Dr. R. A. Bolam, who describe their methods and results in the *British Medical Journal*. The increasing employment of electricity within the last few years has demonstrated, by the accidents to workmen engaged in its generation and distribution, that danger is involved. Two opinions are held as to the cause of death in such cases, viz.: (1) that death is due to failure of the respiratory center (d'Arsonval); (2) that it is due to sudden arrest of the heart's action. From the appearance presented by the internal organs after death, some physiologists have maintained that death is due to asphyxia. But other evidence suggests that death is not due to failure of the respiratory center. In the experiments carried out by Professor Oliver and Dr. Bolam, an alternating current was used, and death appears to have resulted from heart, rather than respiratory, failure. Whilst in some of the experiments death seemed to be due to contemporaneous cessation of the respiration and heart's action, yet in most there was ample demonstration that the organ first to be arrested was the heart, for breathing was observed to continue rhythmically for a brief period, and then irregularly and feebly before stopping. There is reason to believe that only in the case of very high voltages with currents considerably above the potential usually required to kill the animal is there simultaneous stoppage of heart and respiration. Primary cessation of the heart's beat is, without doubt, the general rule, while

under no circumstances did the authors succeed in causing primary arrest of respiration followed by failure of the heart. It follows from this that resuscitation in apparent death from electric shock is made much more difficult than if the result was brought about by respiratory failure. With reference to these experiments, Dr. Lewis Jones calls attention, in the *Electrical Review*, to a similar investigation carried out by him in 1895, using a continuous current.—*London Nature.*

THE THIRD-RAIL SYSTEM IN THE SNOW.

The great snow storm of January 31, 1898, which raged over New England, has proved that a railroad can be operated by the third-rail electric system under the most adverse conditions. That portion of the New York, New Haven and Hartford Railroad, between New Britain and Hartford, operated by electricity, was kept open during the whole of that day, and the trains were run with but a few seconds delay in the schedule, while the steam trains on the main lines were held up and delayed for three or four hours.

A heavy snow storm had long been desired by the electrical engineers and railroad officials in order that as severe a test as possible might be applied to the third-rail system. It has been a question whether, with the third rail practically surrounded by snow and moisture, the current leakage would seriously affect the operation of the motors on the cars. This question was settled by the snow storm. There was absolutely no leakage, and, once the heaviest part of the snowfall was removed by the snowplows, no interruption in the motor-car service occurred.

Col. N. H. Heft, chief electrical engineer of the New York, New Haven and Hartford Railroad, and the engineers of the General Electric Company, express great satisfaction at the performance of the entire system under the severe climatic conditions.—*Electrical World.*

BOOK NOTICE.

Elementary Form, or outlines of concrete geometry. A key to the sequence of figure. By the Rev. W. F. C. Morsell, Springfield, Mass. Milton Bradley Co., 1897. (Price, Manual and blocks, $5.00; Manual alone, $1.00).

The author has elaborated what appears to be a philosophical method of studying the relationships of elementary geometrical forms and of their composites. The text is devoted to the exposition of the system and is intended to be illustrated and explained in concrete form with the aid of a set of blocks invented by the author.

The system devised by Mr. Morsell is quite original and should prove very helpful to teachers and pupils in simplifying the study of applied mathematics. W.

Franklin Institute.

[*Proceedings of the stated meeting held Wednesday, April 20, 1898.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, April 20, 1898.

The President, MR. JOHN BIRKINBINE, in the chair.

Present, 198 members and visitors.

Additions to membership since last report, 29.

Prof. F. L. Garrison, chairman of the Committee on Library, gave an account of the present state of the work of re-arranging the library in the new fireproof stack-room, and congratulated the members on the circumstance that the work of transferring and re-arranging was now practically completed, and in a very satisfactory manner. He stated that a large amount of binding and repairing had been found necessary, and that the efforts made by the Committee to secure a fund of several thousand dollars, by subscription, for this purpose, had met with encouraging response.

Prof. L. F. Rondinella, chairman of the Committee on Science and the Arts, made a report of the present state of the work of that body. He renewed the request that the members of the Institute would aid the Committee by suggesting meritorious subjects for investigation.

Mr. Wm. F. Roberts gave a description of a novel form of motor actuated by carbon dioxide, the details of which are reserved for publication. The subject was illustrated by the exhibition and operation of several types of the motor, and evoked a very general discussion.

Mr. B. C. Batcheller, engineer of the Batcheller Pneumatic Tube Company, Philadelphia, read a communication on "Recent Progress in the Development of Pneumatic Despatch Tubes." The speaker gave a brief historical sketch of the subject, and described the special features of the pneumatic tube systems in the United States postal service, which embody the latest improvements. The subject was fully illustrated with the aid of lantern views.

The subjects above named were referred, for investigation and report, to the Committee on Science and the Arts.

Mr. H. Lyman Sayen described and illustrated the operation of certain improvements in X-ray tubes, which he had devised. These improvements consist, substantially, in a form of construction, whereby any desired and predetermined degree of vacuum may be attained by suitable adjustment, and, when once attained, is automatically maintained.

Adjourned.

WM. H. WAHL, *Secretary.*

COMMITTEE ON SCIENCE AND THE ARTS.

[*Abstract of proceedings of the stated meeting held Wednesday, April 6, 1898.*]

PROF. L. F. RONDINELLA, in the chair.

Reports on the following subjects were considered:

Franklin Institute Grand Medal.—Discussed and referred to a special committee, to consider and report upon the scope of the medal.

Trolley Car Fender.—Henry Lotzgesell, Philadelphia. Discussed and referred back to the sub-committee to consider certain alleged anticipatory inventions.

Improvements in Turnbuckles.—E. W. Merrill, Brooklyn, N. Y. Passed first reading.

Swivel Loom.—Hermann Willmunder, Philadelphia. Passed first reading.

The Abatement of the Smoke Nuisance.—Referred by the Institute. Passed first reading.

Disinfectant Ejector.—Wm. B. Hollingshead, Bronxville, N. Y. Passed first reading.

Tidal Motor.—Ernest Markmann, Philadelphia. The Committee voted to reconsider its report on this case, and referred the subject to a new sub-committee.

The following reports were adopted:

Wave Motor.—Henry Lotzgesell, Philadelphia.

ABSTRACT.—This motor is fixed to a triangular float placed with its apex towards the approaching waves, and on each side of it are pivoted three vertical shafts having large vanes on their lower ends, which receive the impact of the waves and impart a partial rotation to the said shafts. The intermittent action of the waves is transformed into a continuous motion by well-known mechanical artifices, and the same may then be transmitted in any des red manner.

After having been moved back by the impact of a wave, the vanes are returned to their former position by weights appropriately applied to the vertical shafts, and other mechanical devices are employed when necessary to hold any or all the vanes out of action. [See U. S. Letters-Patent, No. 597,118, January 11, 1898.

The report finds that the invention exhibits considerable ingenuity, but in the absence of practical tests no opinion is ventured as to its mechanical or commercial usefulness. [*Sub-committee.*—John Haug, chairman; G. Morgan Eldridge.

Automatic Water-Supply Cut-off.—Samson Borgnis, Philadelphia.

ABSTRACT.—The object of this device is to effect, automatically, the stoppage of a flow of water after a certain predetermined interval of time. It consists of a valve which, when opened by hand, permits a flow from the source of supply. On the outlet side of the valve thus opened is a wheel with radial paddles, revolving in a tightly fitting case by the inflowing stream of water. The paddle-wheel, by means of connected gearing, is caused to release the valve previous y opened by hand, effecting thereby a closure in the pipe

and the stopping of the flow of water. The interval of time elapsing between the opening of the valve by hand and its automatic closing is determined by the ratio of the gearing.

As shown in the model presented for the examination of the sub-committee, the device does not register a predetermined volume of water and then cut off the supply, as in the case of filling a tank, but is adapted rather for service as an attachment to a garden hose for watering lawns, in which the mechanism might be adjusted for a certain length of time for flow through a sprinkler.

The sub-committee investigating the device commends the applicant for the conception of the idea aimed at by his invention, and for the ingenuity displayed in his attempt to produce a mechanism for automatically controlling the flow of water and preventing waste. The report suggests in its conclusions certain modifications of the device which in the committee's opinion would render it more efficient and useful. The report was made advisory. [*Sub-Committee.*—Wm. M. Barr, chairman; Thos. P. Conard.]

Pneumatic Bicycle.—J. M. Baker, Lafayette Hill, Pa.

This inventor proposes to construct a bicycle frame so that both front and rear wheels are mounted to vibrate within the frame-bearings with a spring or cushioned support, and thus overcome the jolt and shock incident to riding.

Applicant submits to the committee certain sketches exhibiting the essential features of his plan of construction, and asks for advice as to its presumable utility. The report advises the inventor that his ideas are impractical. [*Sub-Committee.*—H. R. Heyl.]

FRANKLIN INSTITUTE AWARDS

which the Committee on Science and the Arts is authorized to grant or recommend, in the name of the Institute, in recognition of inventions and discoveries:

CERTIFICATE OF MERIT.—The Committee on Science and the Arts is authorized to award and issue to persons by said Committee adjudged worthy a certificate of merit for their inventions, discoveries or productions.

EDWARD LONGSTRETH MEDAL OF MERIT.—This award is a medal of silver, and is granted by the Committee for a useful invention, important discovery and meritorious work in, or contribution to, science or the industrial arts.

JOHN SCOTT LEGACY PREMIUM AND MEDAL.—This award comprises a medal of bronze, accompanied by a money premium of twenty (20) dollars, and is issued by authority of the Board of Directors of City Trusts (acting for the City of Philadelphia) on the recommendation of the Franklin Institute (through its Committee on Science and the Arts).

By the terms of the will of John Scott, this award is to be made "to ingenious men and women who make useful inventions."

ELLIOTT CRESSON MEDAL.—This award is a medal of gold and is made by the Committee on Science and the Arts "for some discovery in the arts and sciences, or for the invention or improvement of some useful machine, or for some new process, or combination of materials in manufactures; or for ingenuity, skill, or perfection in workmanship."

The attention of investigators, inventors, authors and others, interested in the terms of the awards here described, is invited to the statement that the Committee on Science and the Arts of the Franklin Institute is organized for the purpose of undertaking the investigation of inventions and discoveries submitted to it, and that in cases deemed worthy of such recognition the grant of one or the other of the foregoing awards will be made or recommended.

The Secretary of the Institute will forward, on application, full information as to the manner of making application to the Committee for an examination and report upon an invention or discovery, or other contribution of value to the arts and sciences.

Members of the Institute are cordially requested to co-operate with the Committee, by bringing to its knowledge, or by recommending for investigation and report, subjects of a meritorious character. W.

SECTIONS.

MINING AND METALLURGICAL SECTION.—*Stated Meeting* held Tuesday, April 12th, Mr. A. E. Outerbridge, Jr., President, in the chair.

Señor Raimundo Cabrera, of New York, presented a communication on "The Mineral Resources of Cuba" (read in the author's absence by Mr. Louis E. Levy). The author gave a comprehensive account of the notable occurrences of useful ores, minerals and building stones in the various provinces of the island, and a historical account of the attempts that have thus far been made to develop and commercially exploit them. The author dwelt strongly upon the past and present hindrances to the rapid development of the mineral industries in Cuba, arising from political conditions.

Mr. Miltiades Th. Armus presented a paper on "The Reduction Works for Silver Ores at Arduana, Sonora, Mexico." The author gave a detailed account of the method successfully pursued, under his superintendence, in the metallurgical treatment of the very complex ores of this district. The above papers were referred for publication.

CHEMICAL SECTION.—*Stated Meeting* Tuesday, April 19th, Dr. W. J. Williams, Vice-President, in the chair.

Dr. Wm. C. Day, Swarthmore, presented a communication on "A Method of Analyzing Commercial Phosphorus," in which he gave the comparative results obtained by the gravimetric and volumetric methods. The paper evoked a very general discussion.

Dr. Robert Bradbury presented a communication "On Chemical Equilibrium," giving a summary of the latest physico-chemical theories bearing on the subject. It was voted that the paper be made the subject of discussion at a future meeting.